

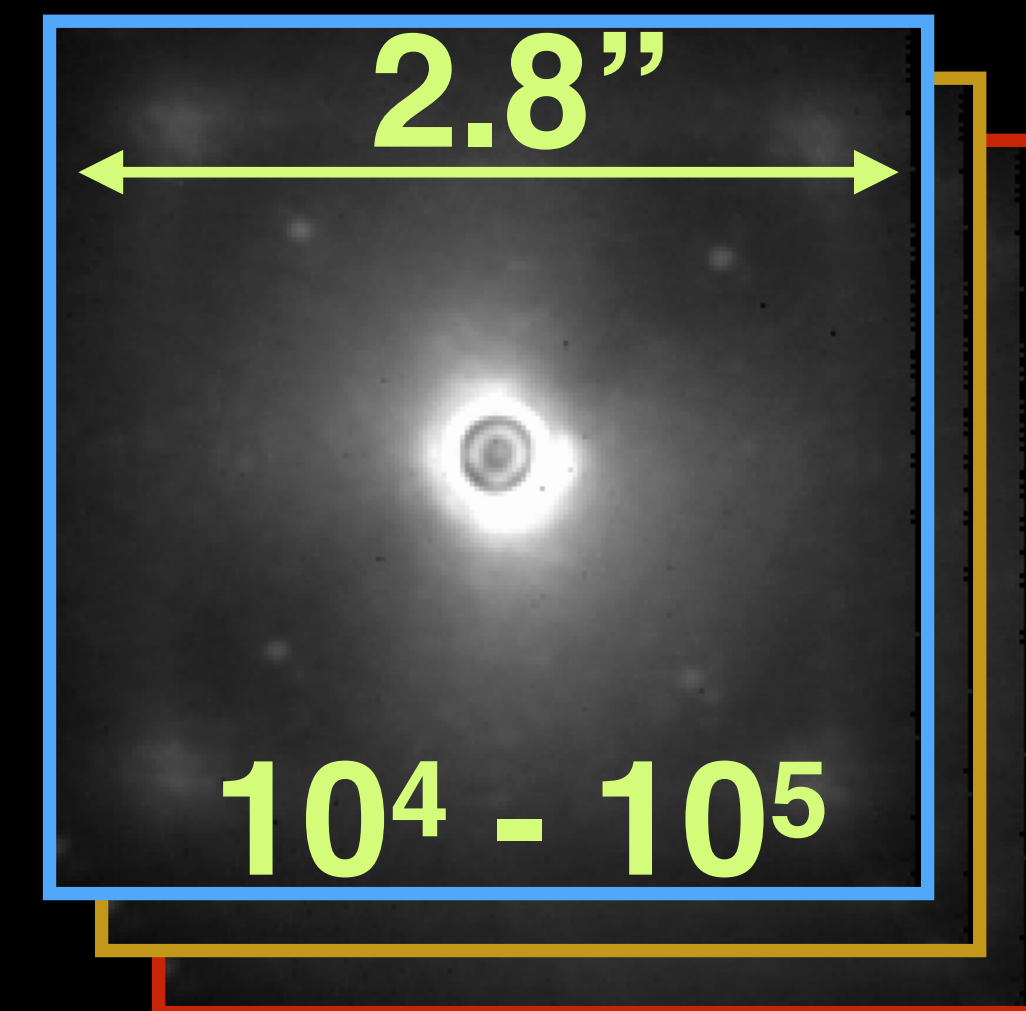
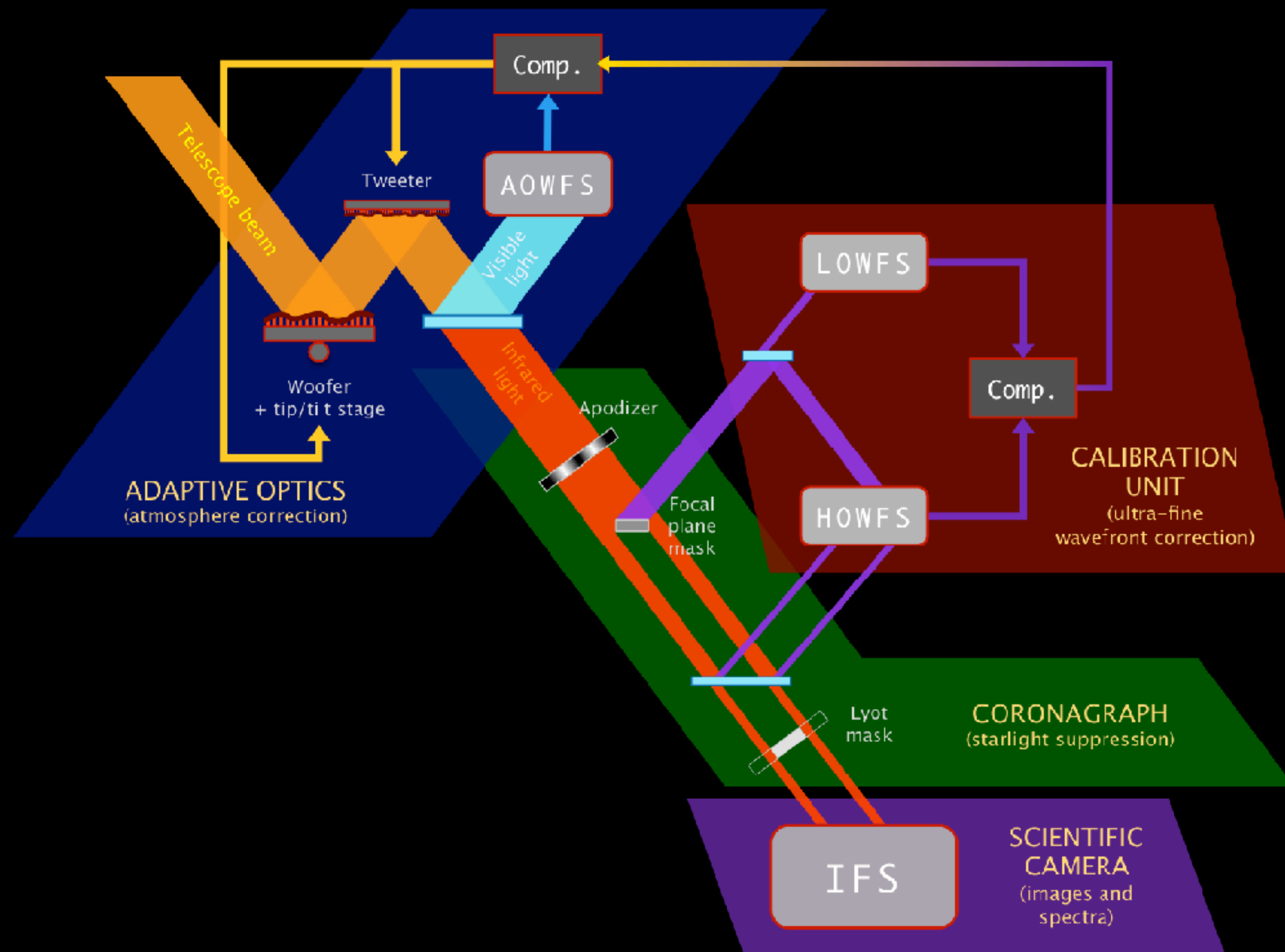
Instrument characterization from telemetry data

Vanessa Bailey

Jet Propulsion Laboratory, California Institute of Technology

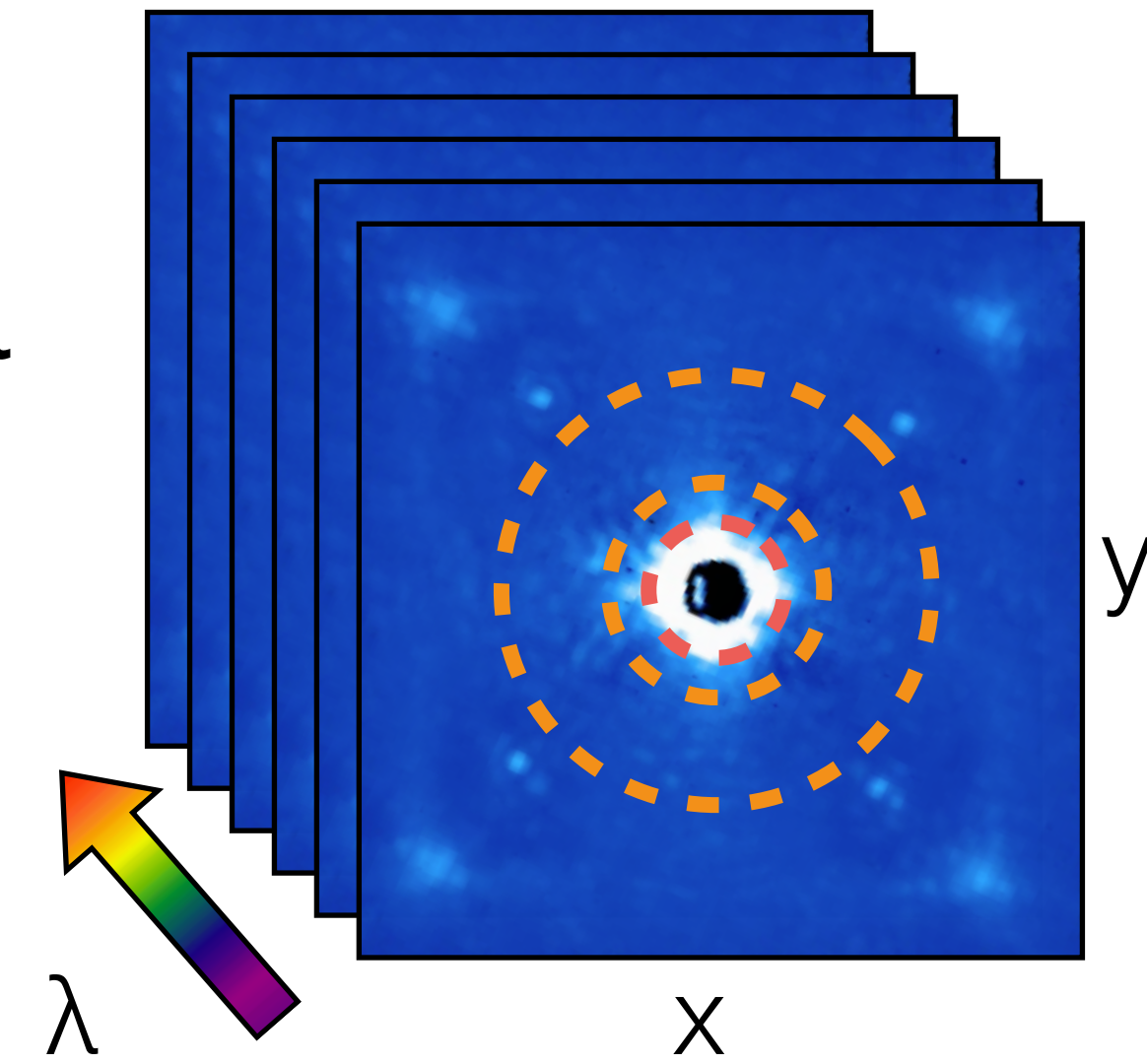


Gemini Planet Imager



Every GPI image has environment & performance data

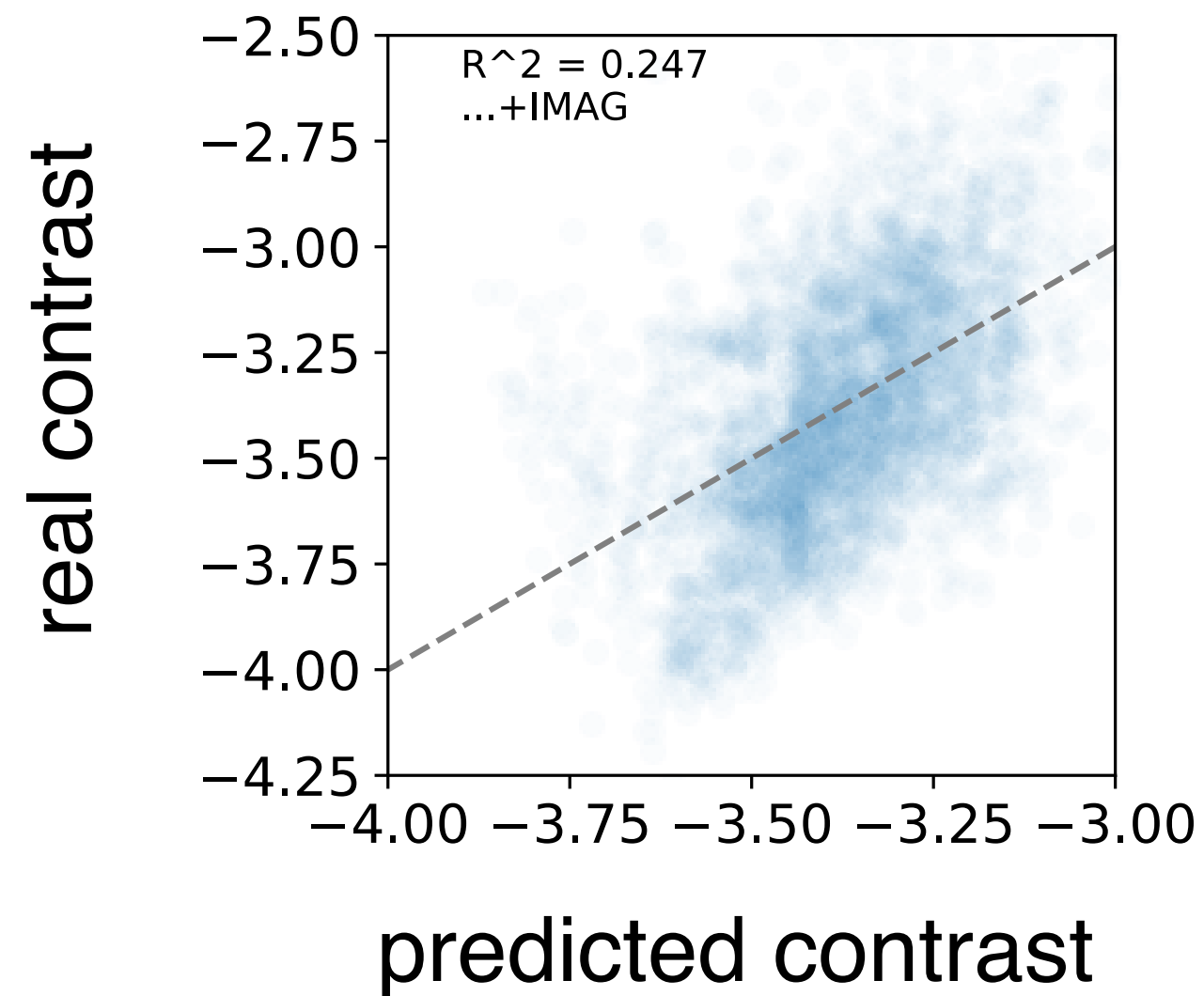
- raw image contrast @ 0.25", 0.4", 0.8"
- ~ WFE
- ~ AO tip/tilt & focus vibration
- environment:
 - seeing (Gemini MASS* & DIMM)
 - wind, temperature
- *Similar analysis for NIRC2 by Jerry Xuan (Pamona) ongoing*



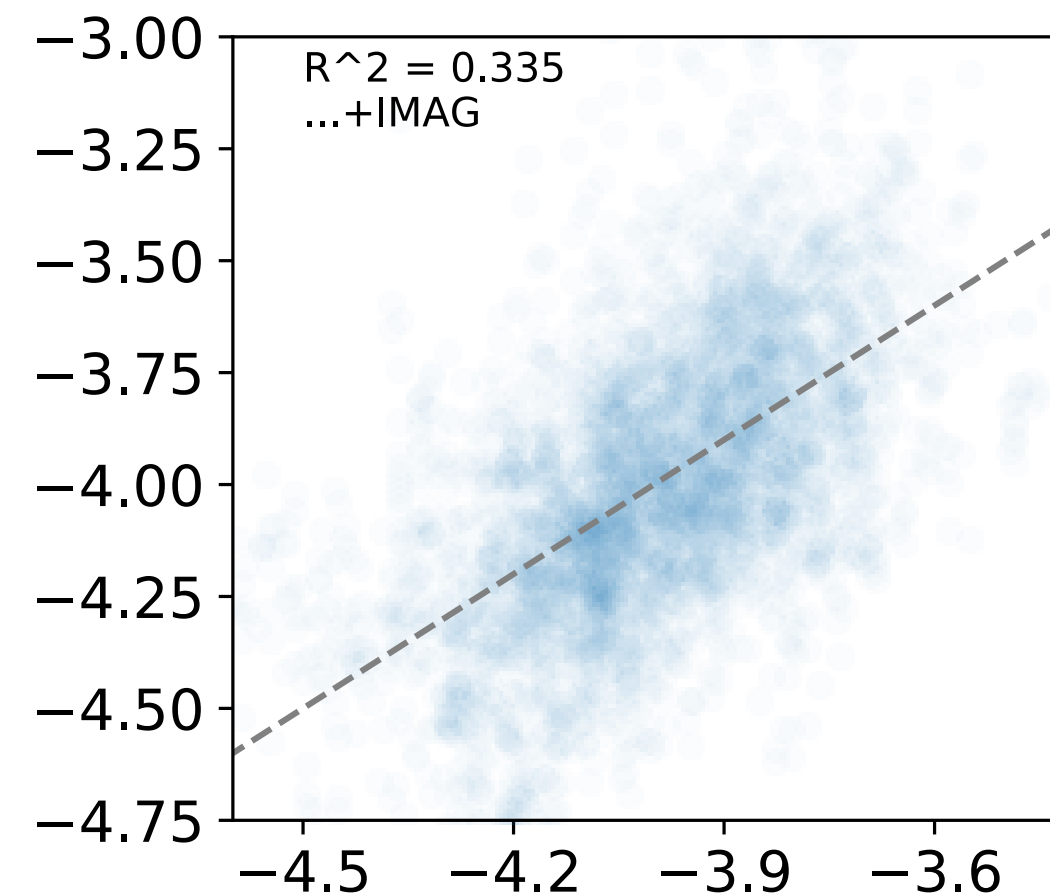
environment parameters alone explain
25-40% of GPI raw contrast variation

- Tau
- DIMM seeing
- $dT = \text{abs}(\text{AO} - \text{amb})$
- I mag

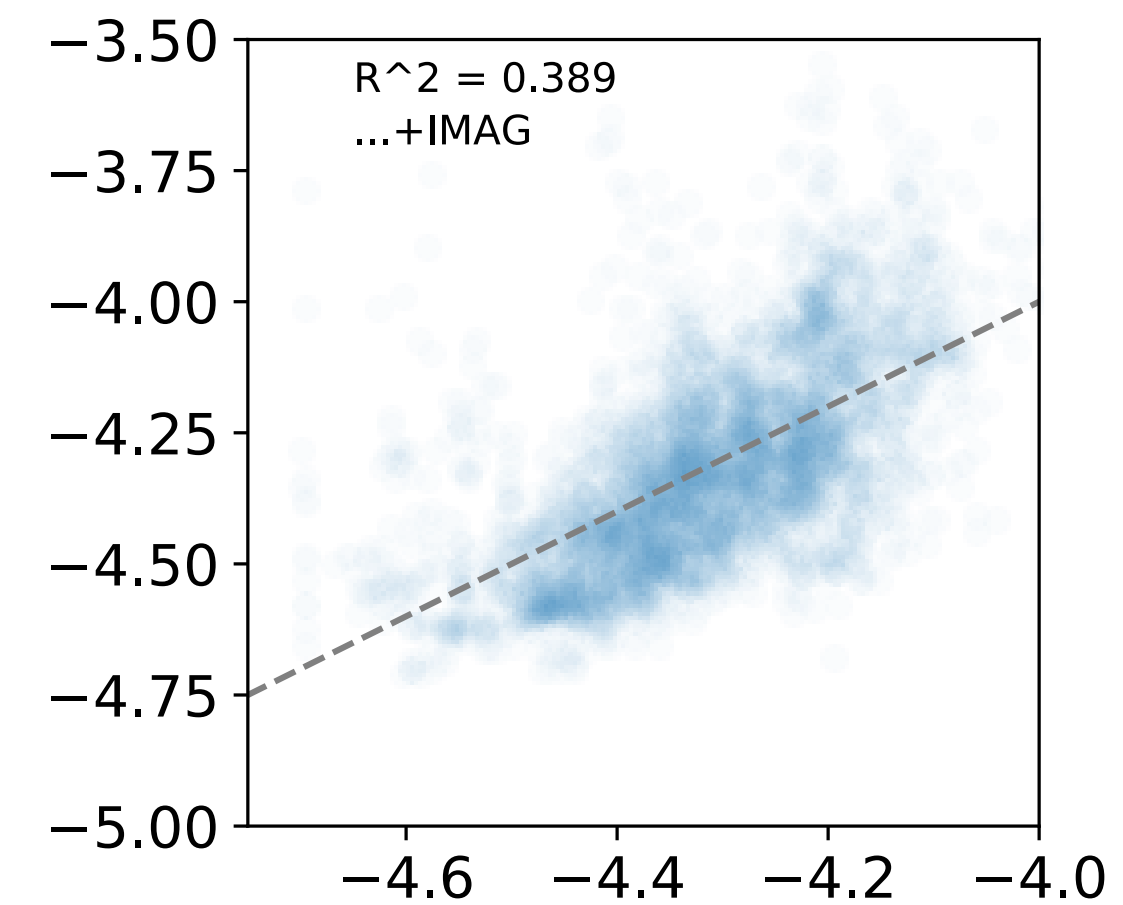
0.25" $R^2=0.25$



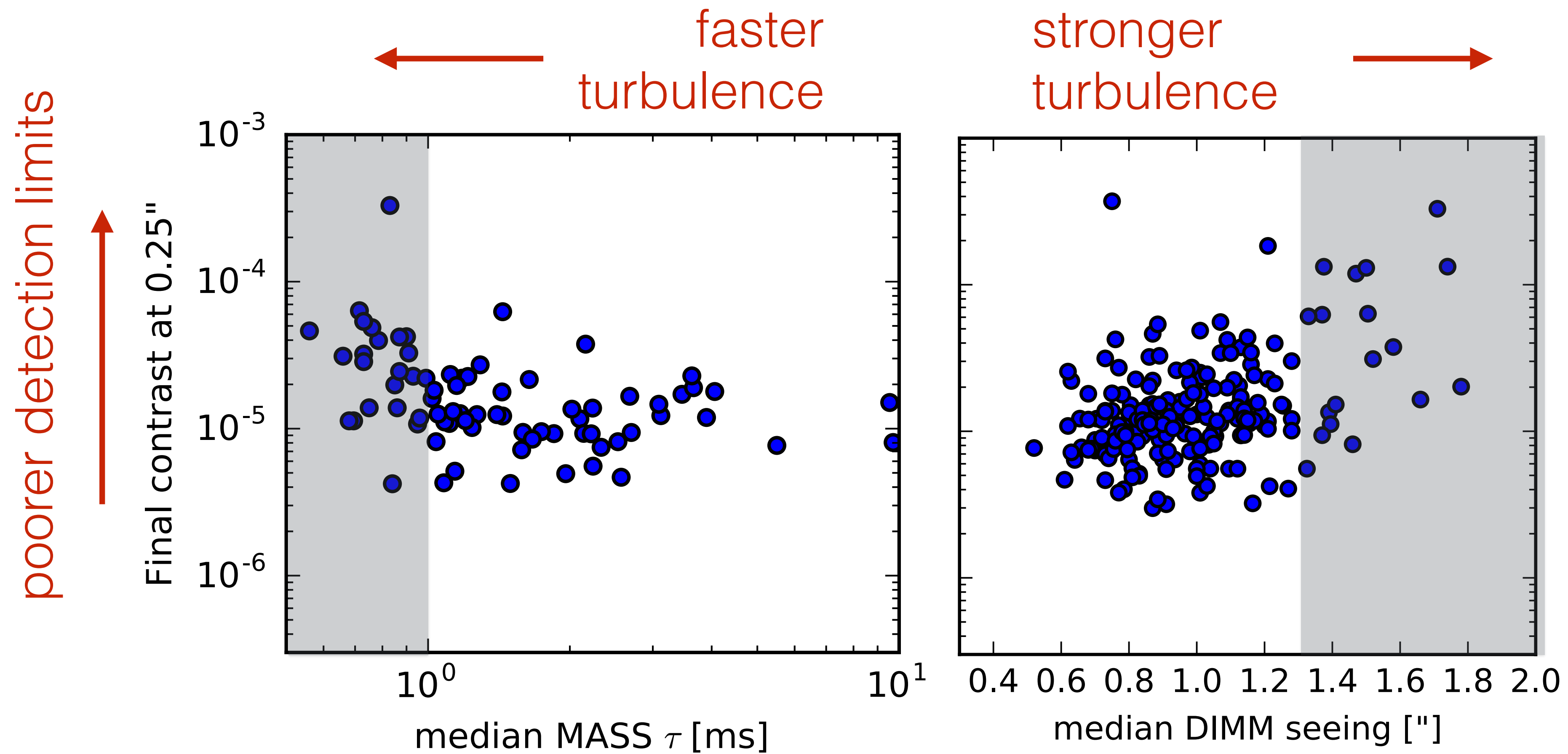
0.4" $R^2=0.33$



0.8" $R^2=0.38$

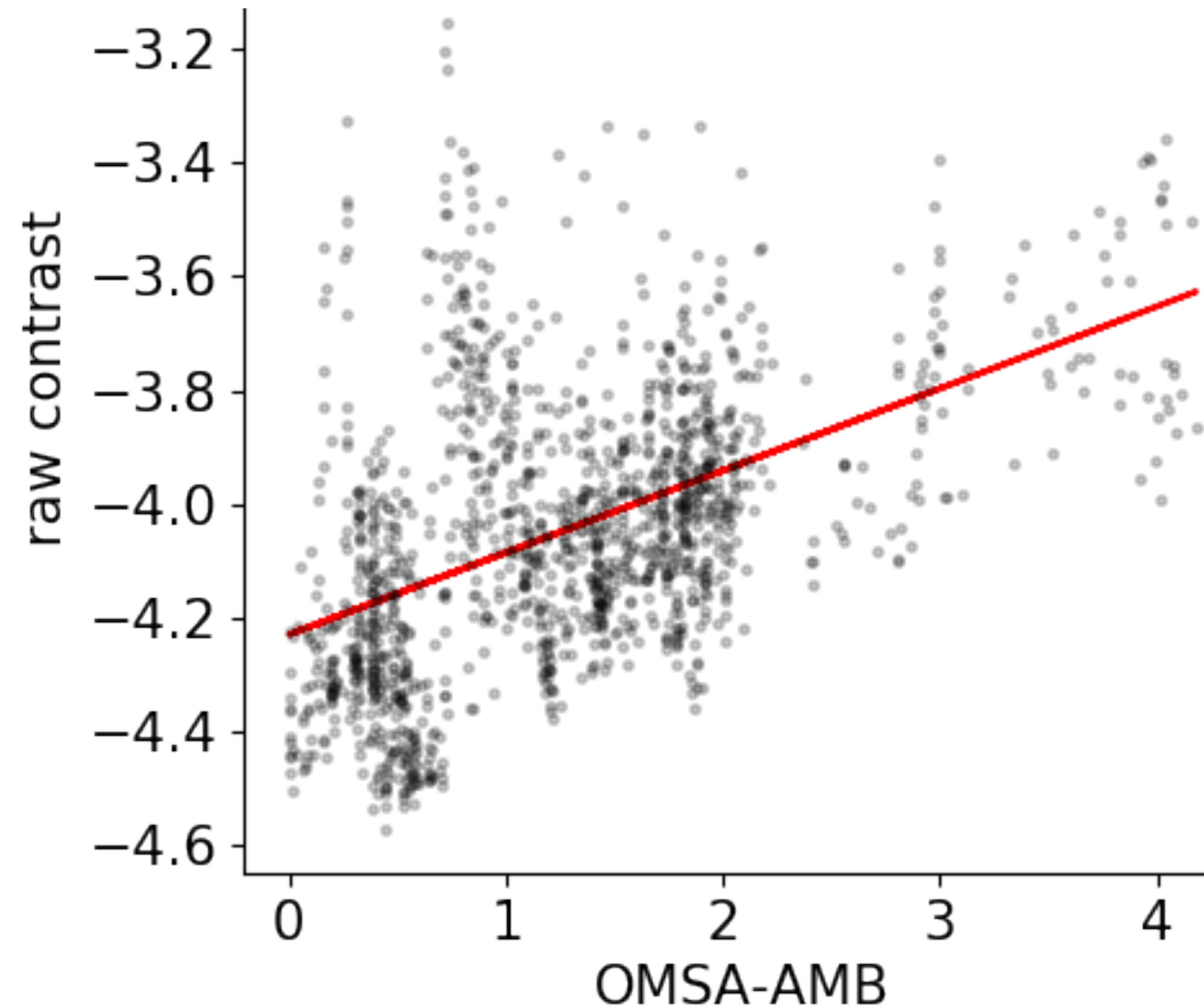


Tau governs final GPI contrast more often than raw seeing does

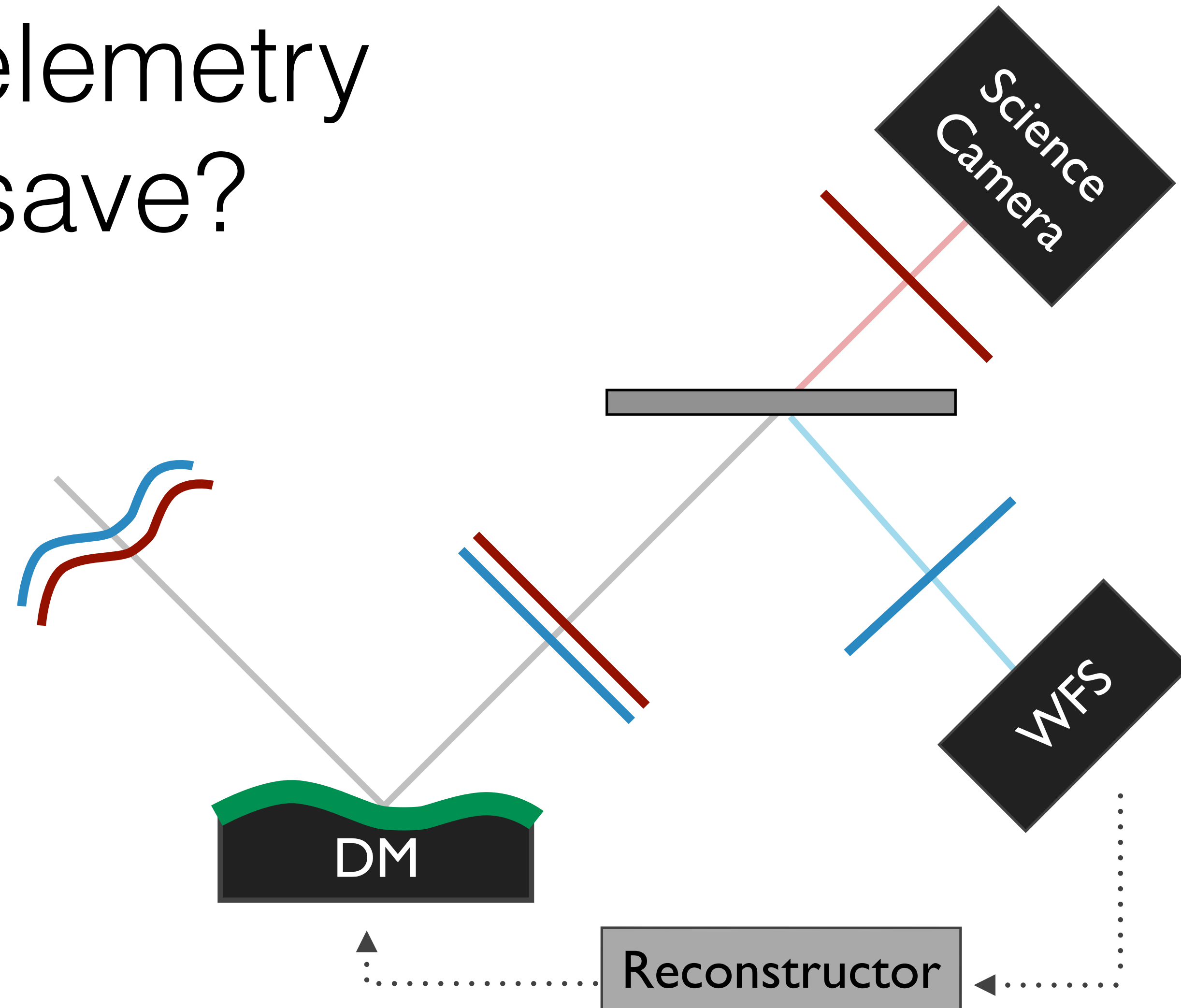


Temperature disequilibrium degrades GPI performance

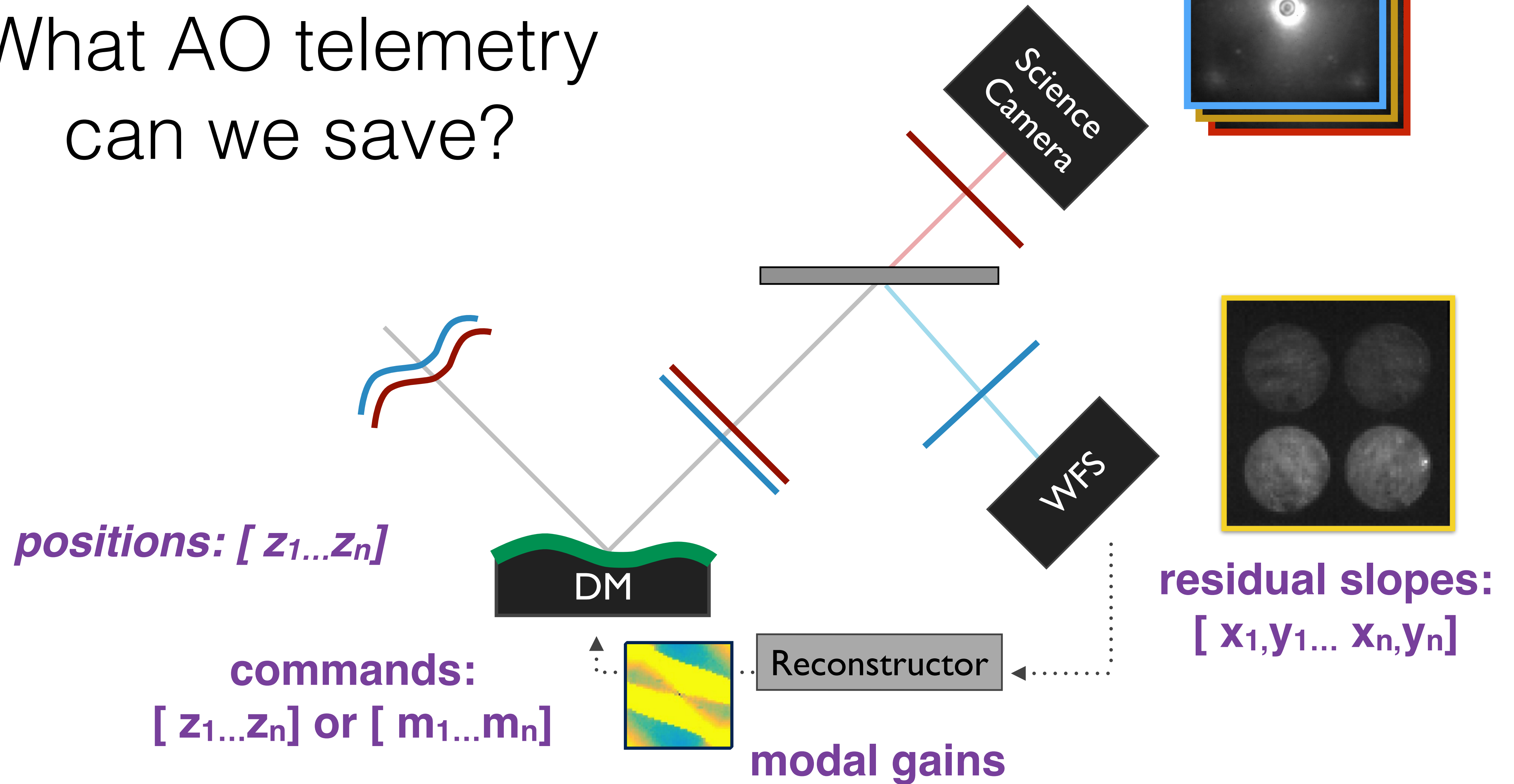
Melisa Tallis



What AO telemetry can we save?

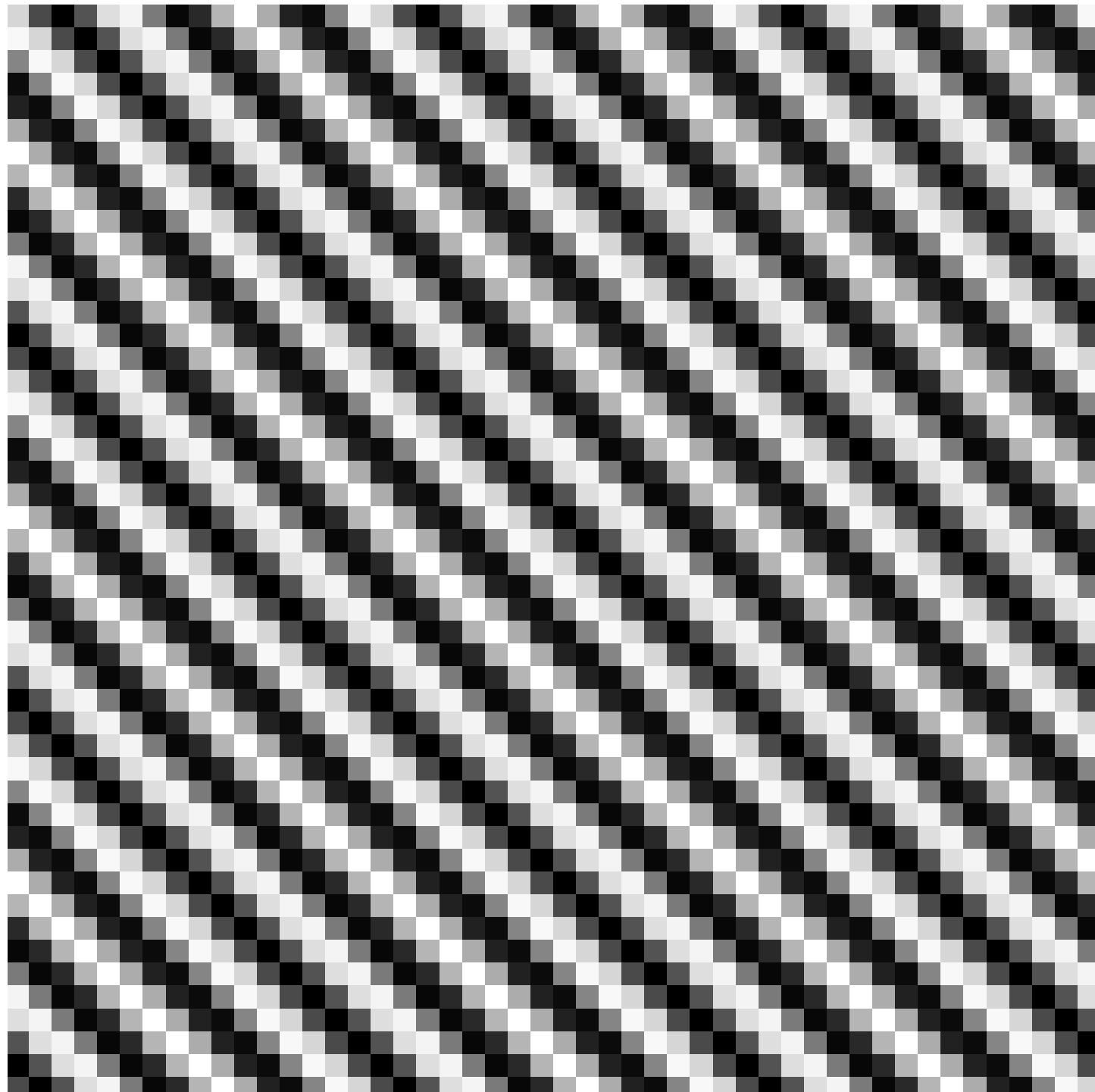


What AO telemetry can we save?

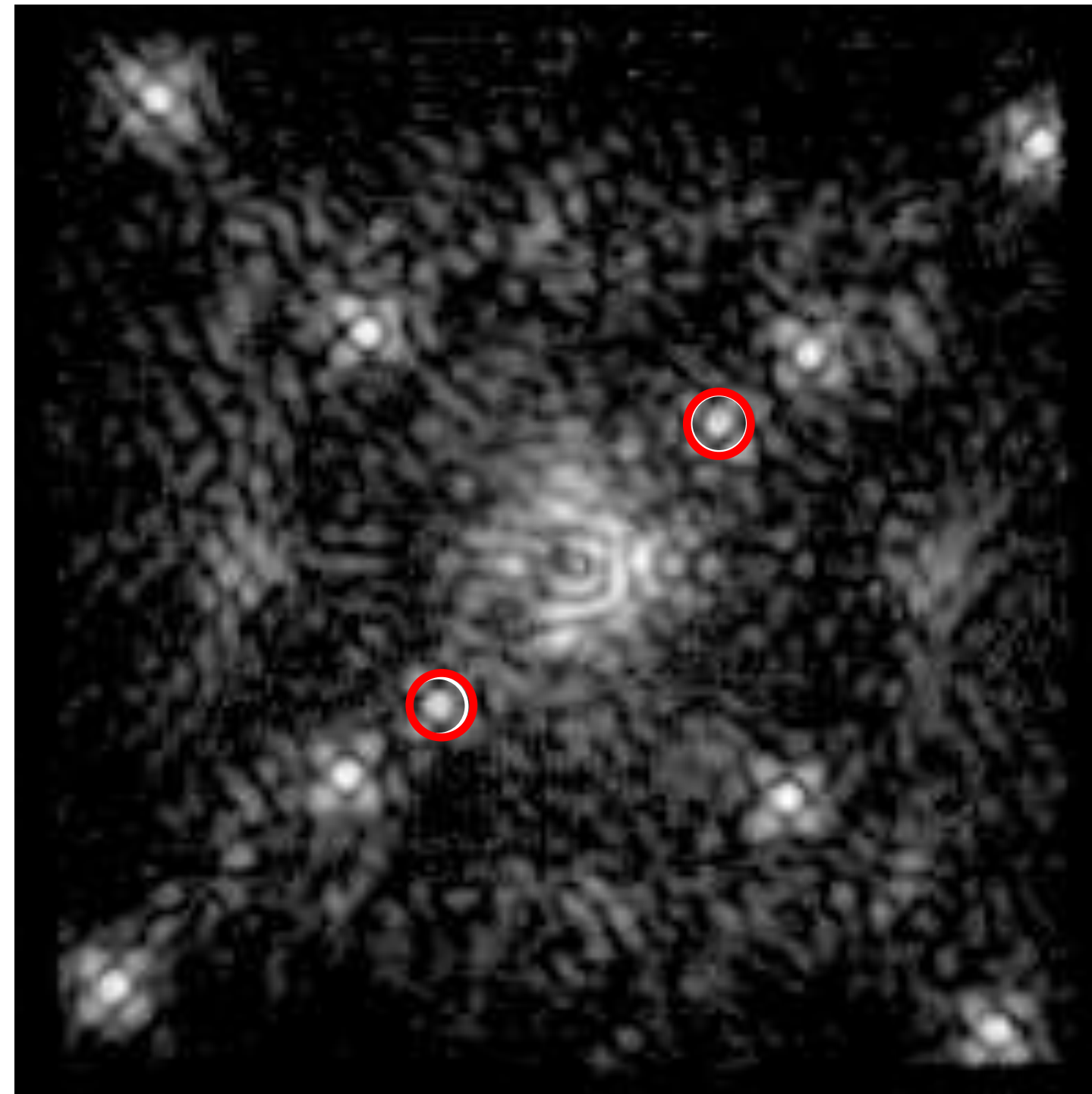


GPI uses a Fourier modal basis set with
individually controlled gains

(spatial) mode

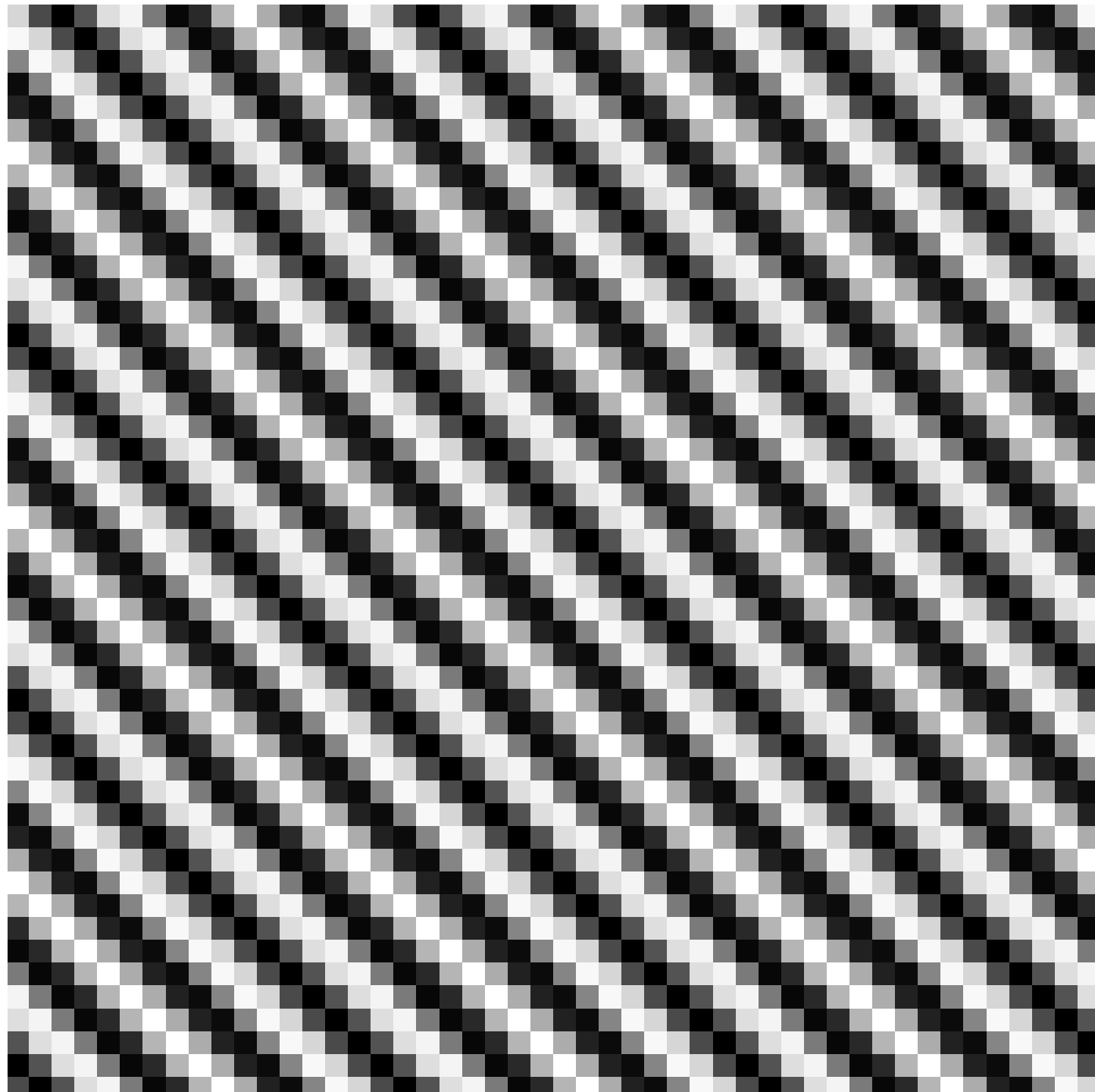


PSF

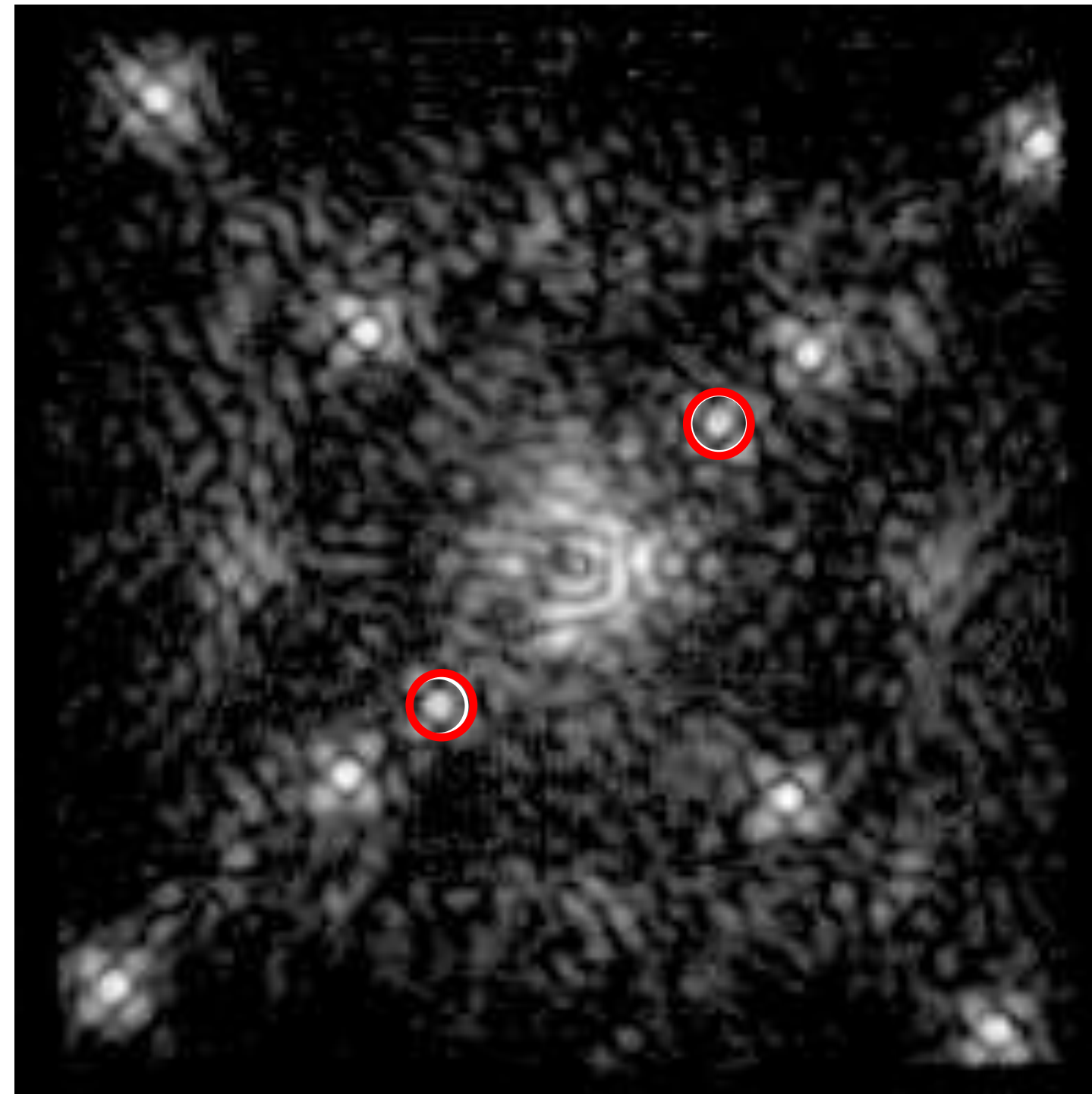


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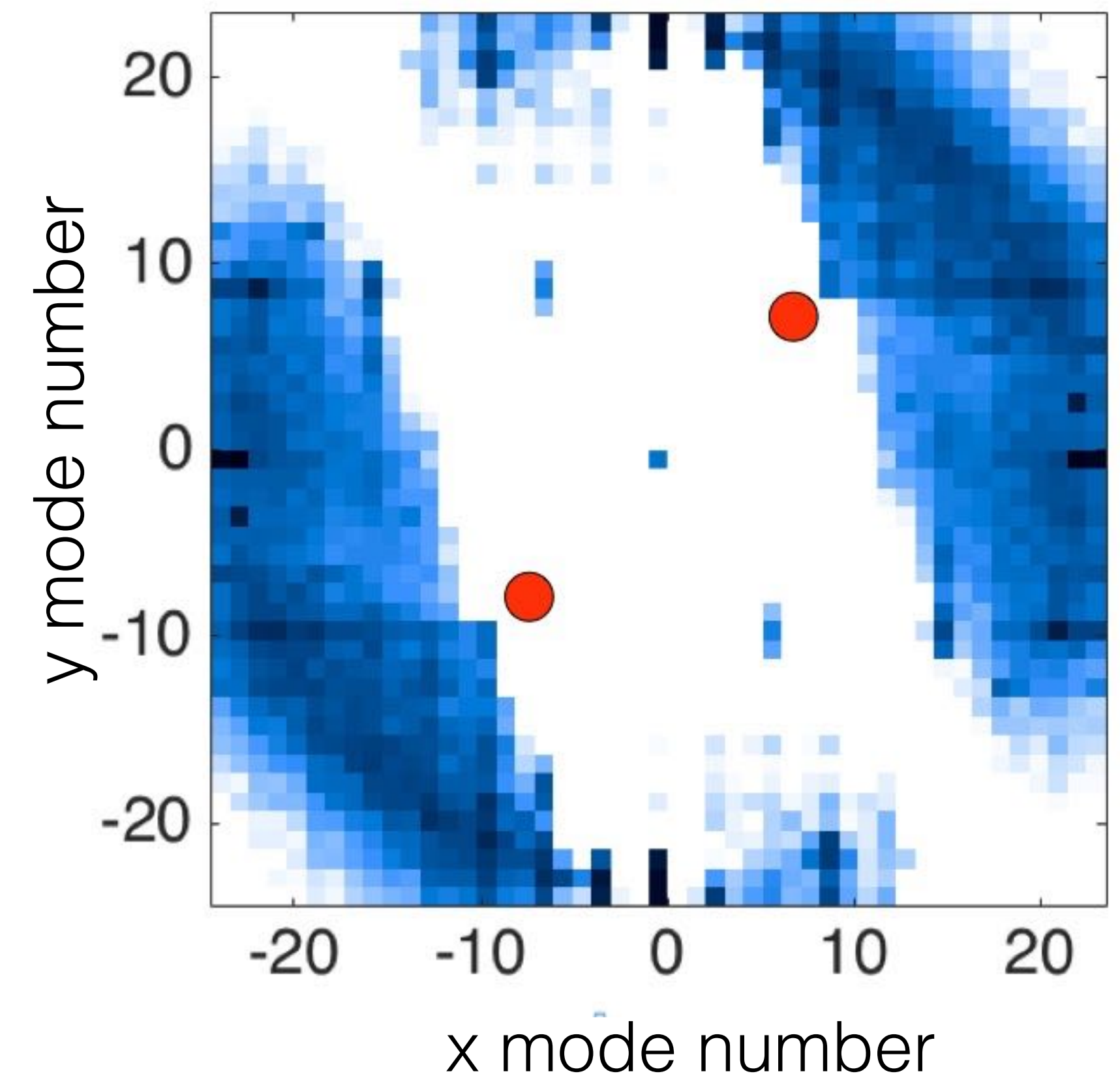
(spatial) mode



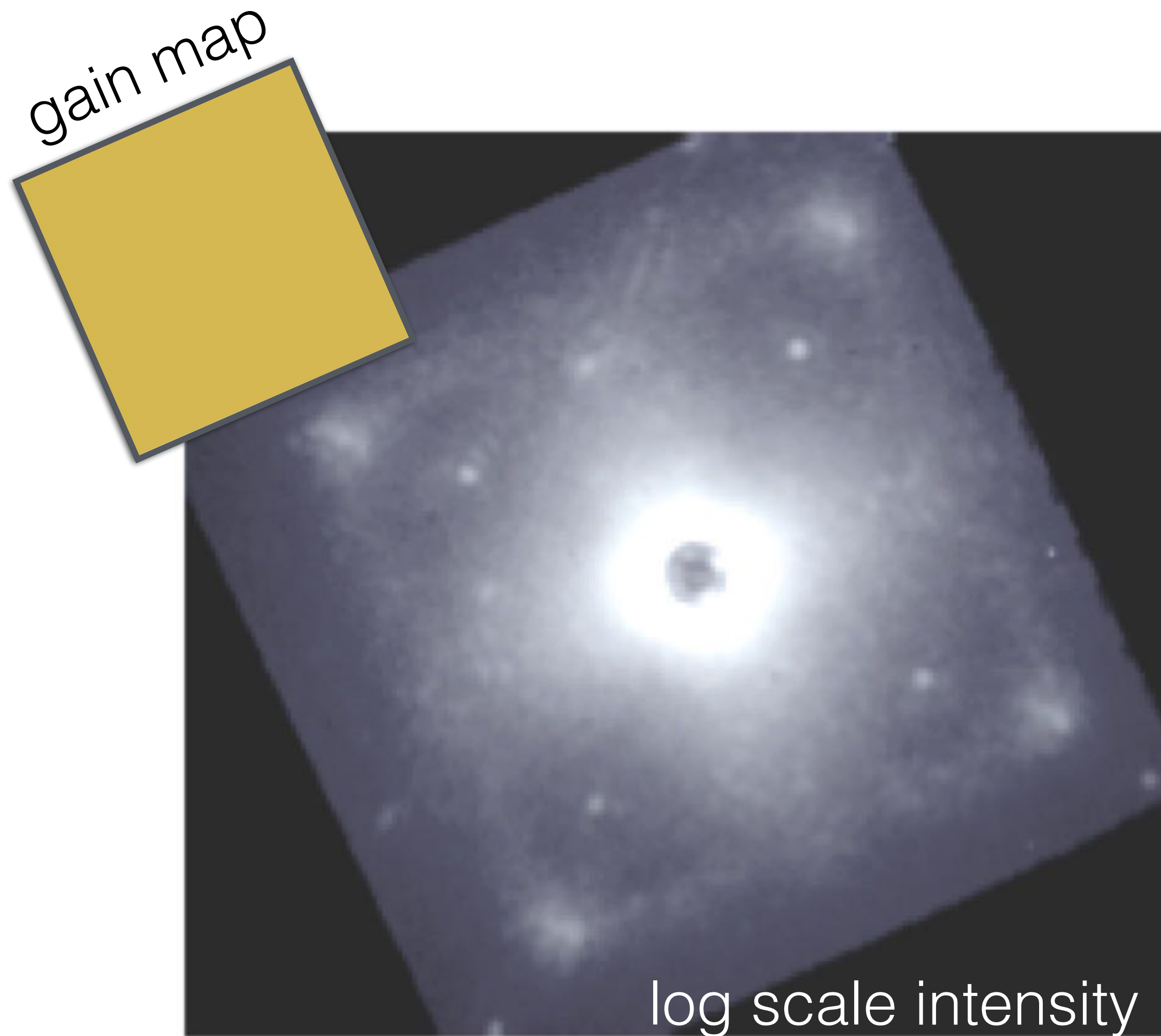
PSF



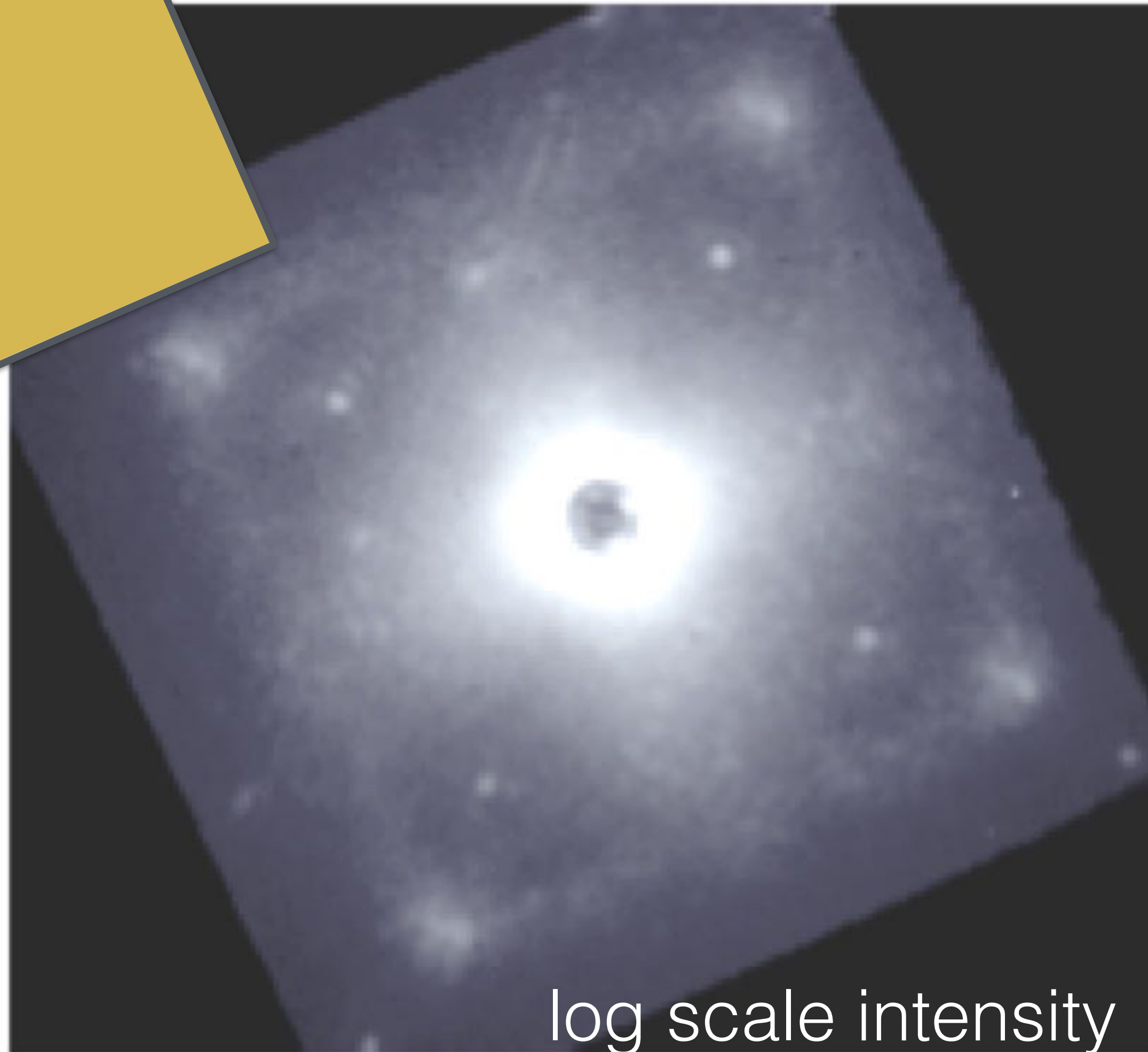
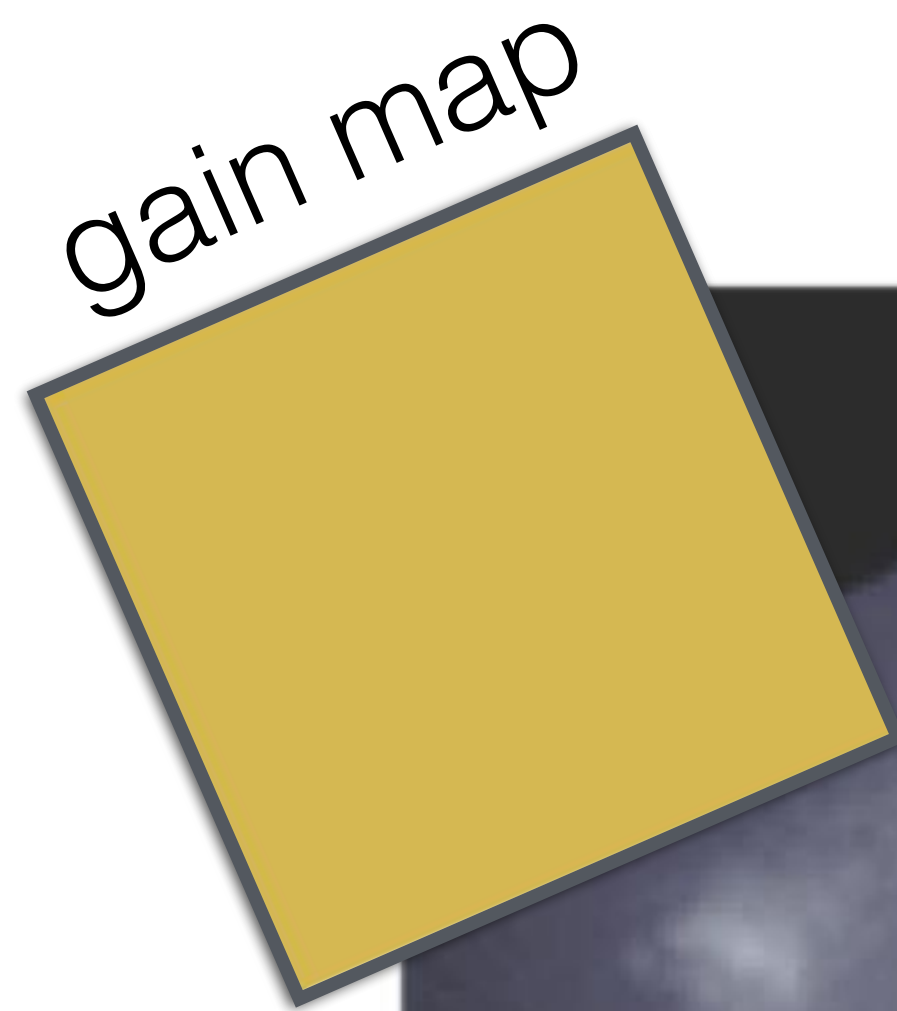
modal gain map



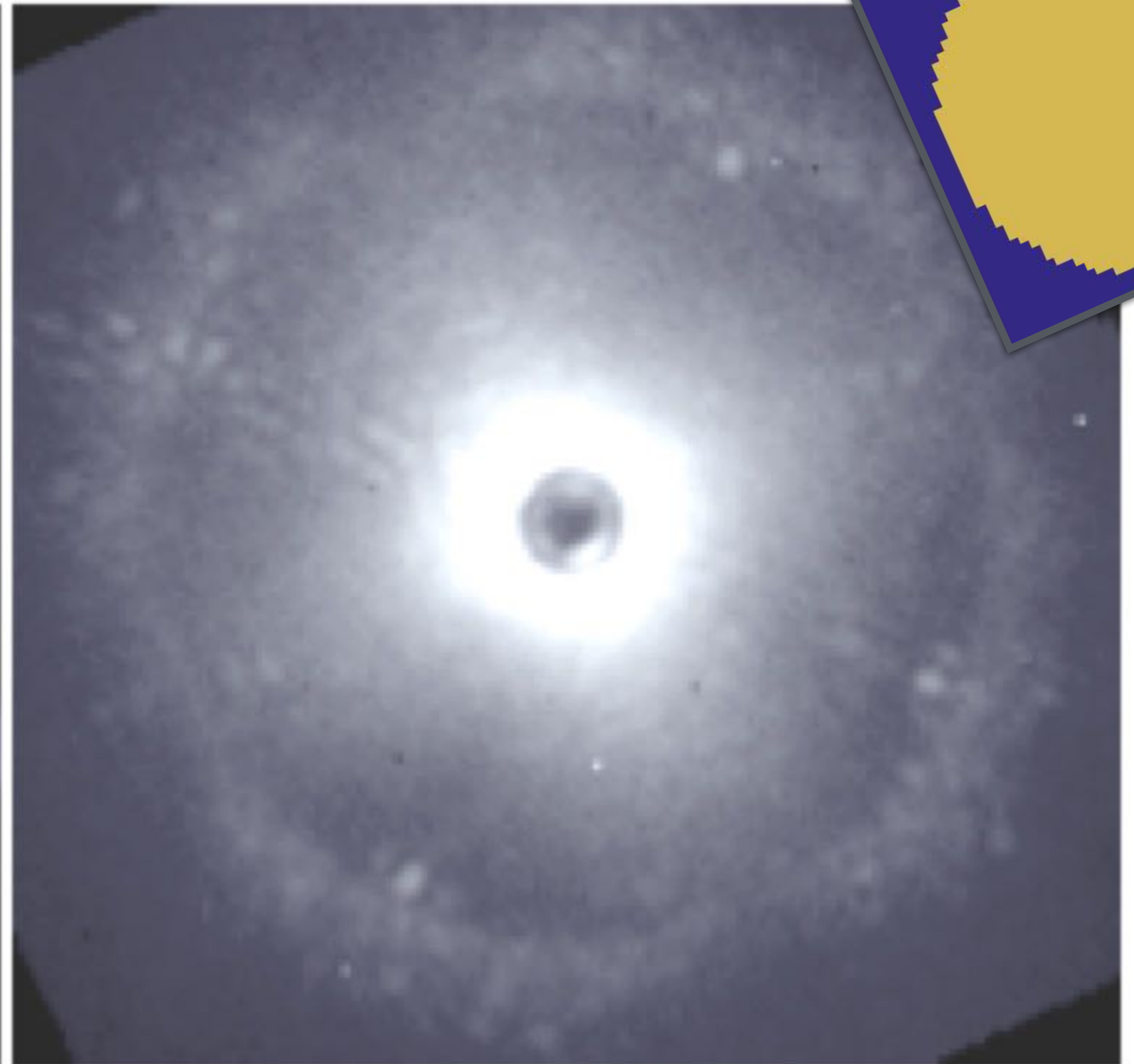
square vs round dark hole



square vs round dark hole

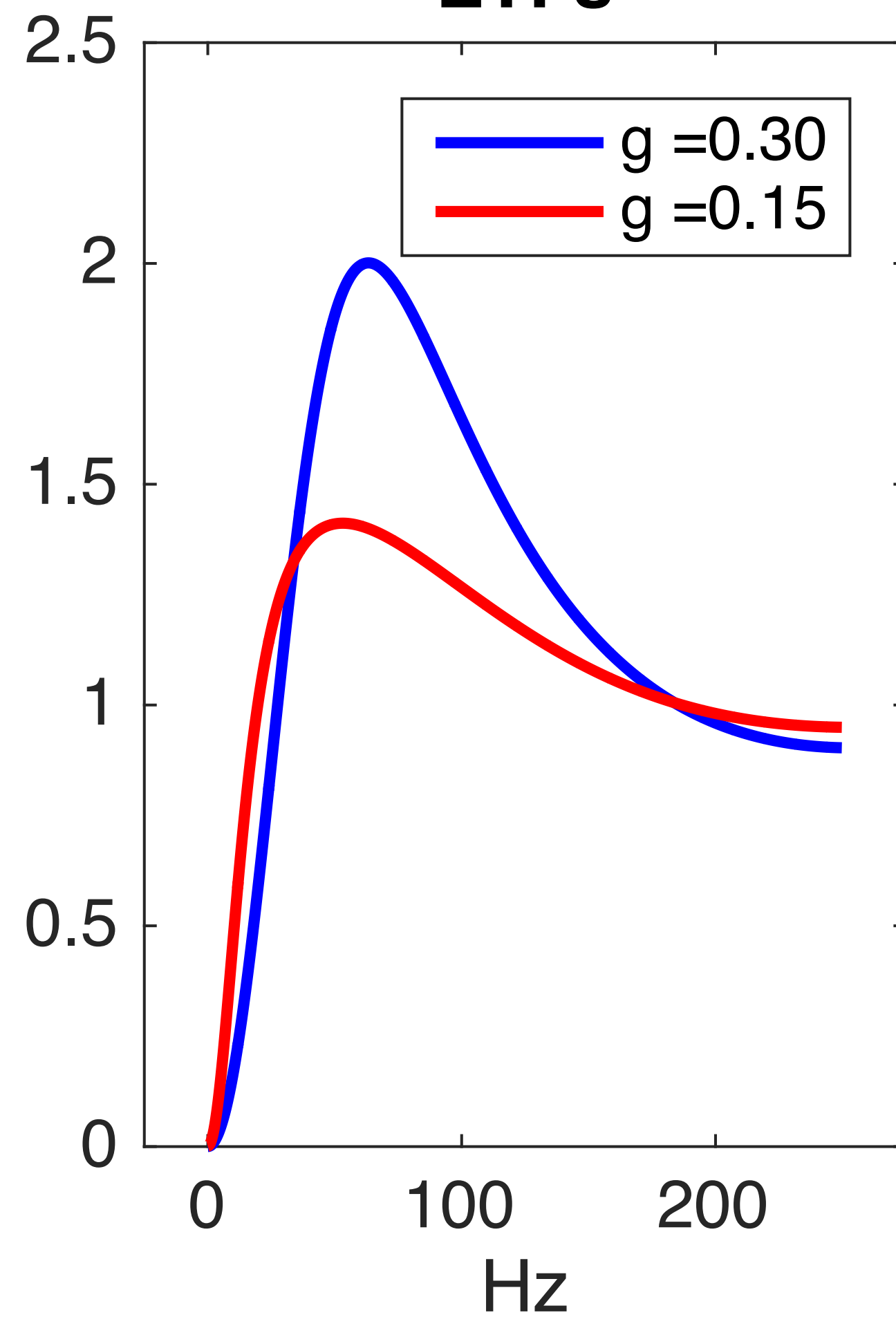


log scale intensity

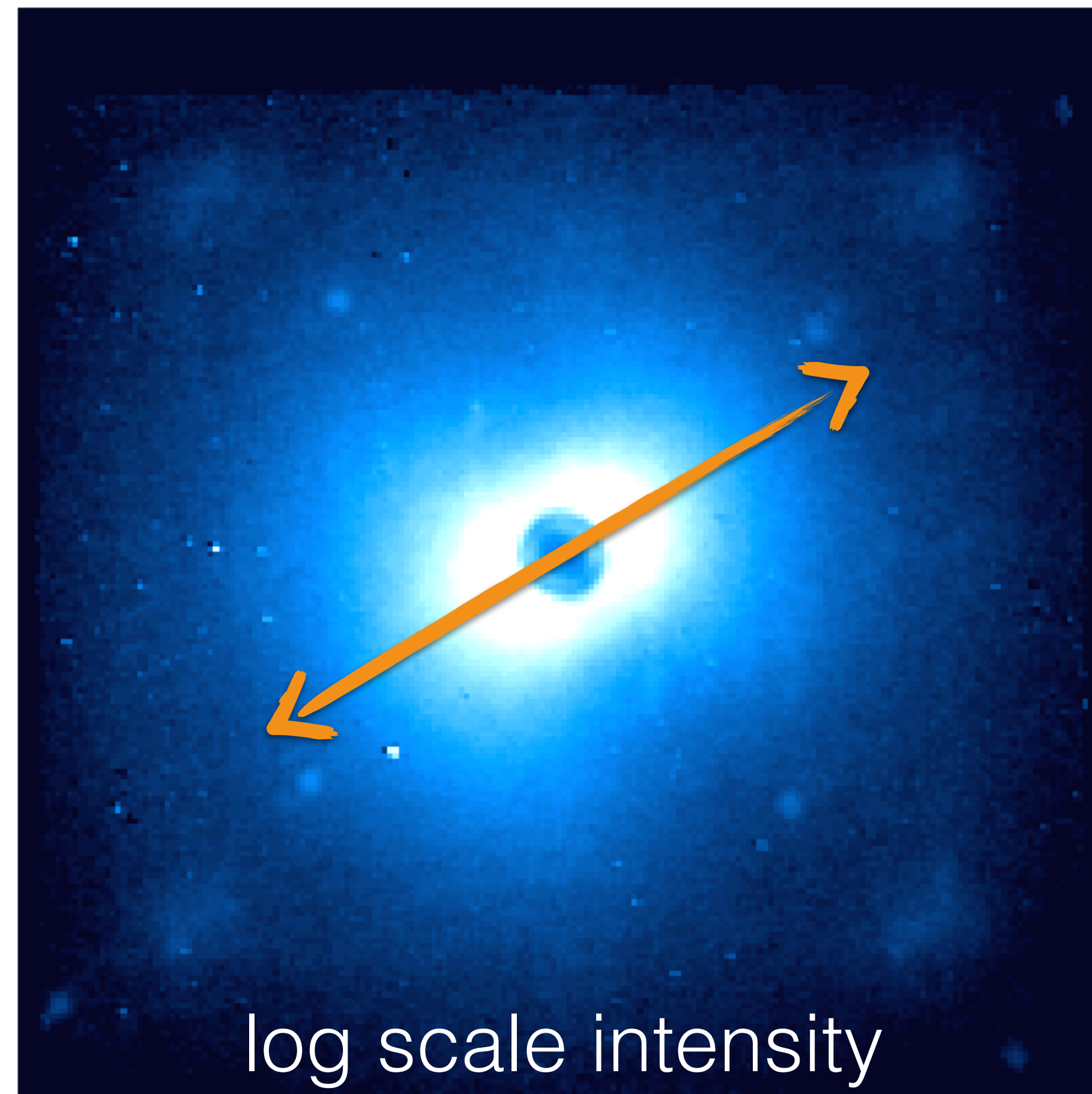


Gains optimized every 8 sec

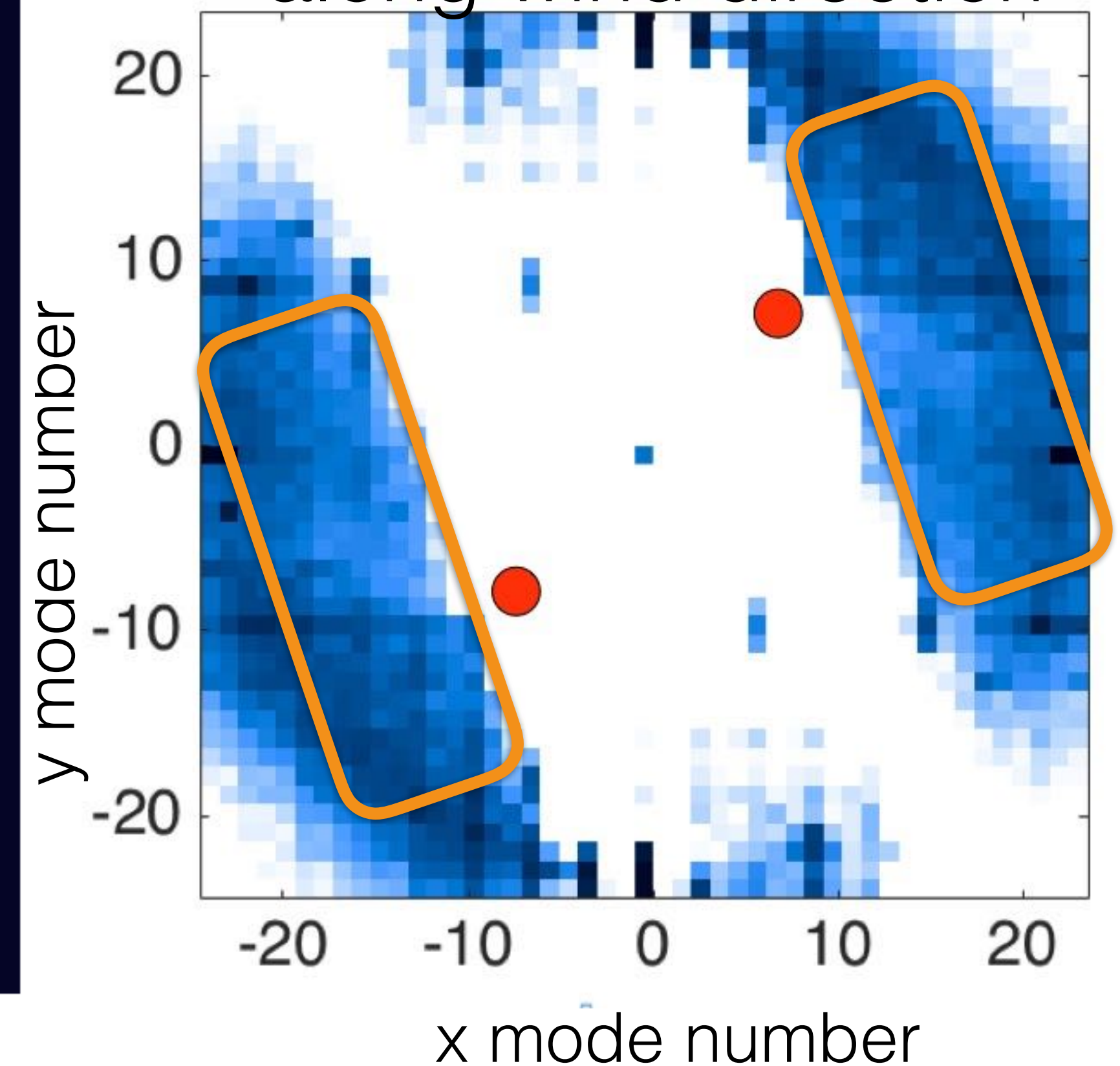
ETFs



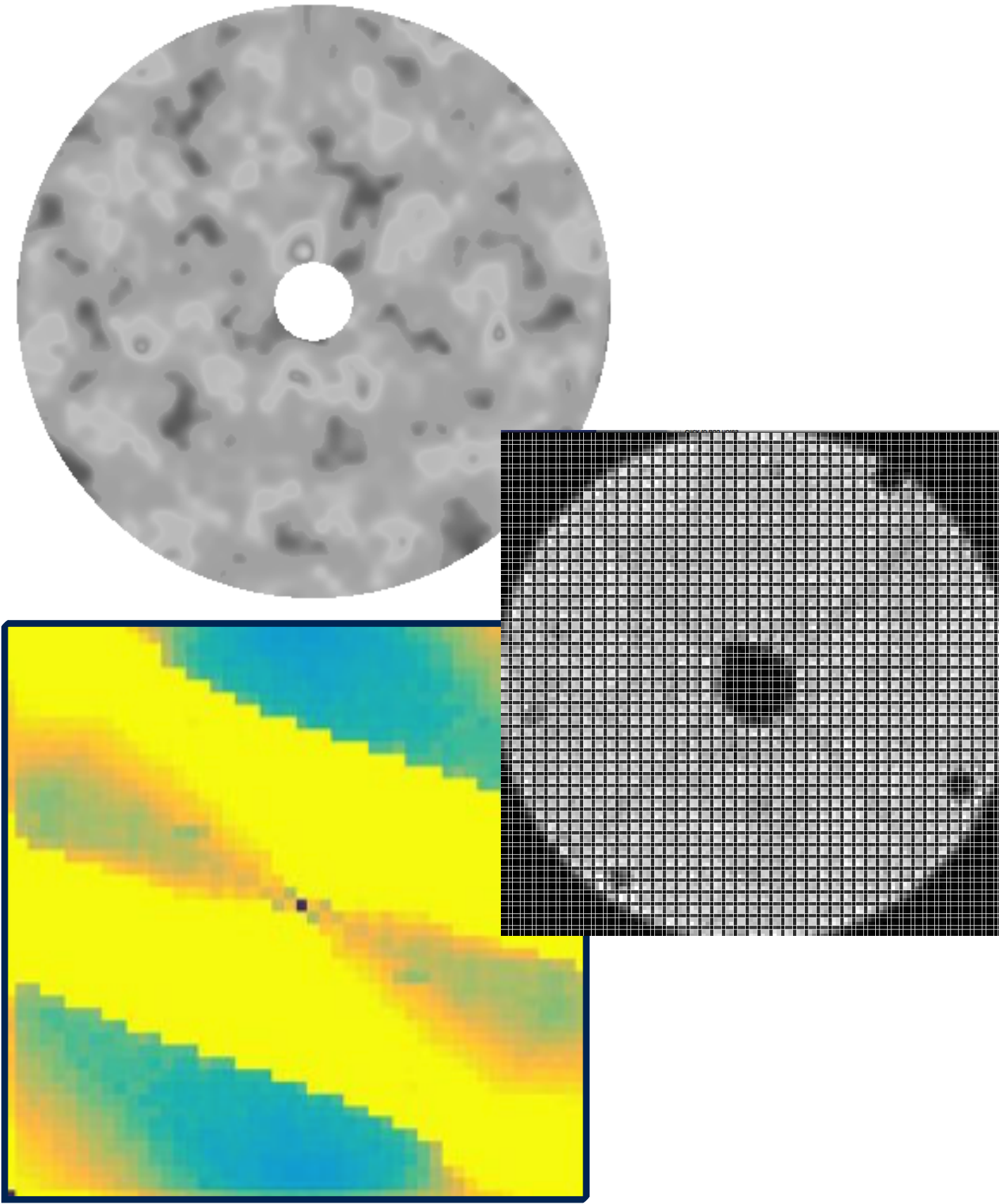
log-scaled IFS image



lag errors -> gains lower
along wind direction



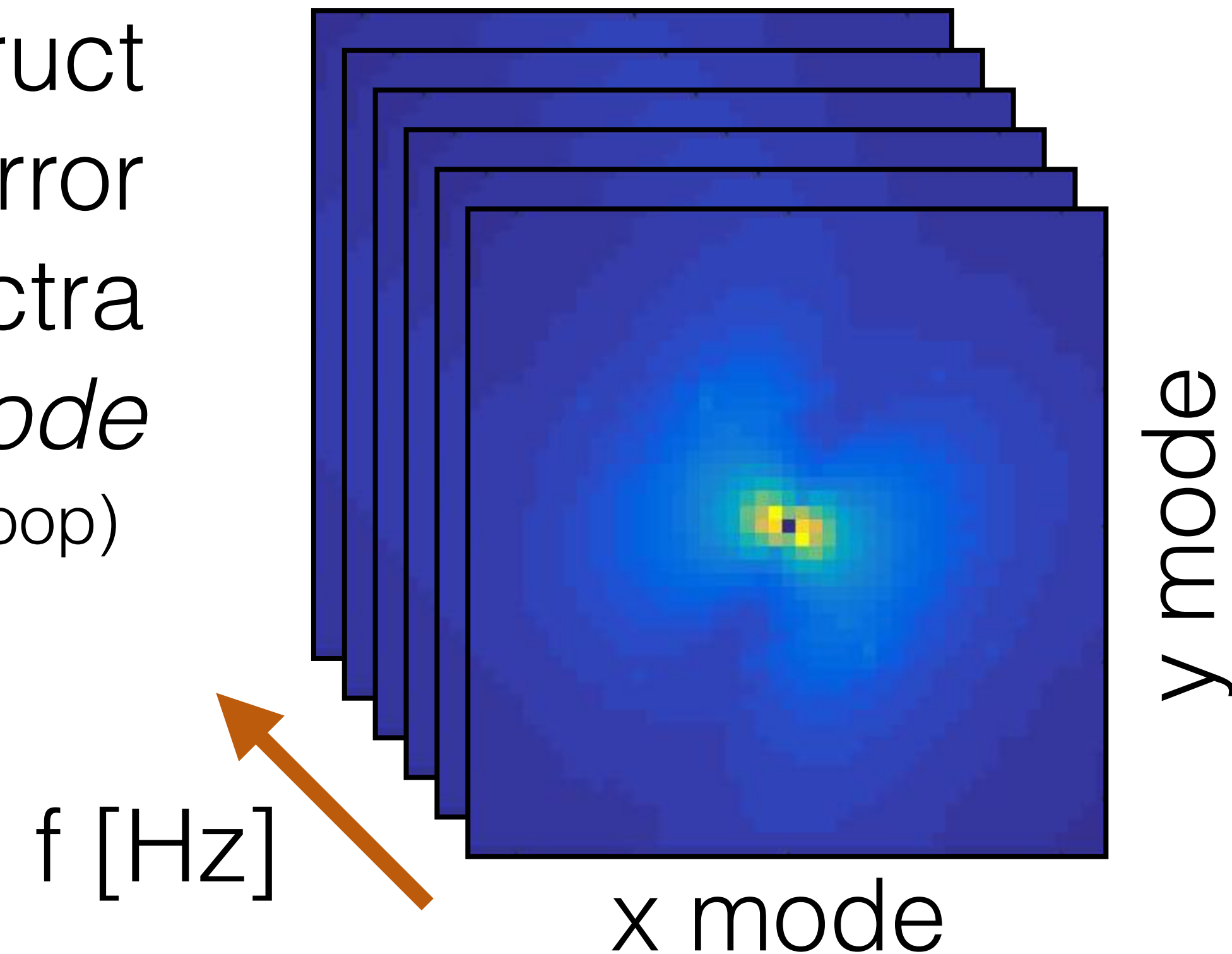
5 - 60sec



Manual AO telemetry sets record detailed information

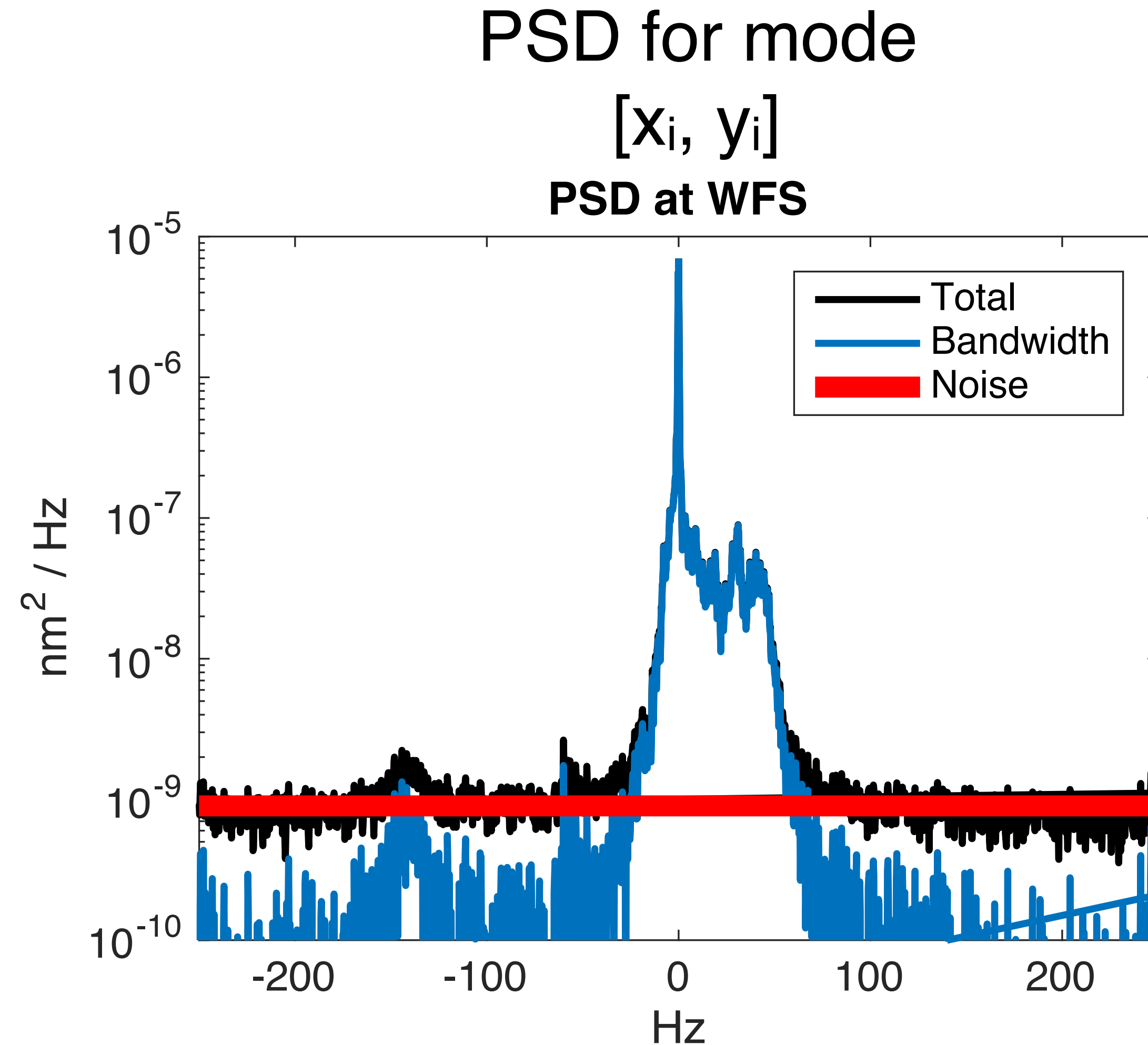
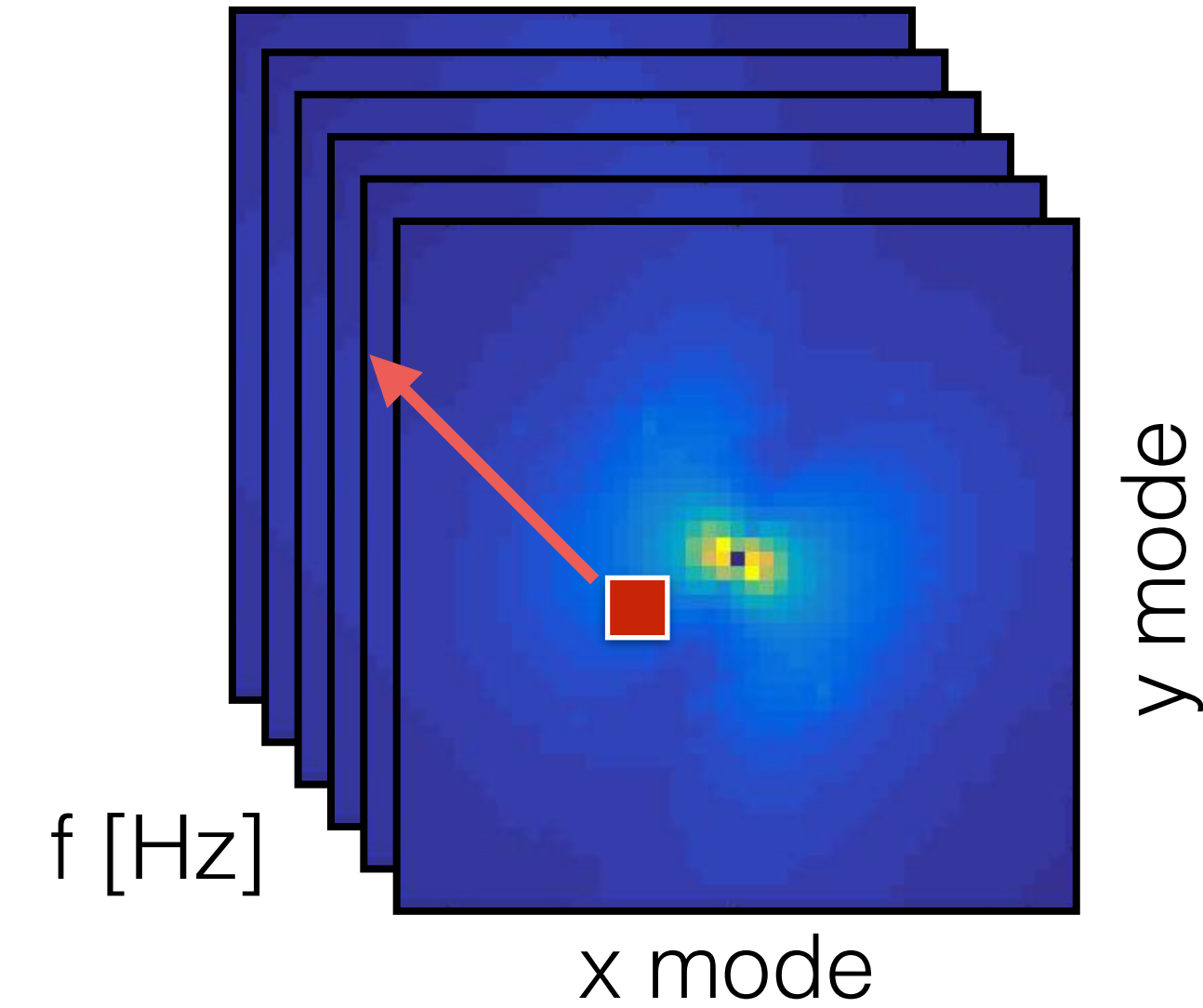


reconstruct
wavefront error
power spectra
for *each mode*
(closed & open loop)



Full data rate
>1GB / min

AO WFE : bandwidth & noise

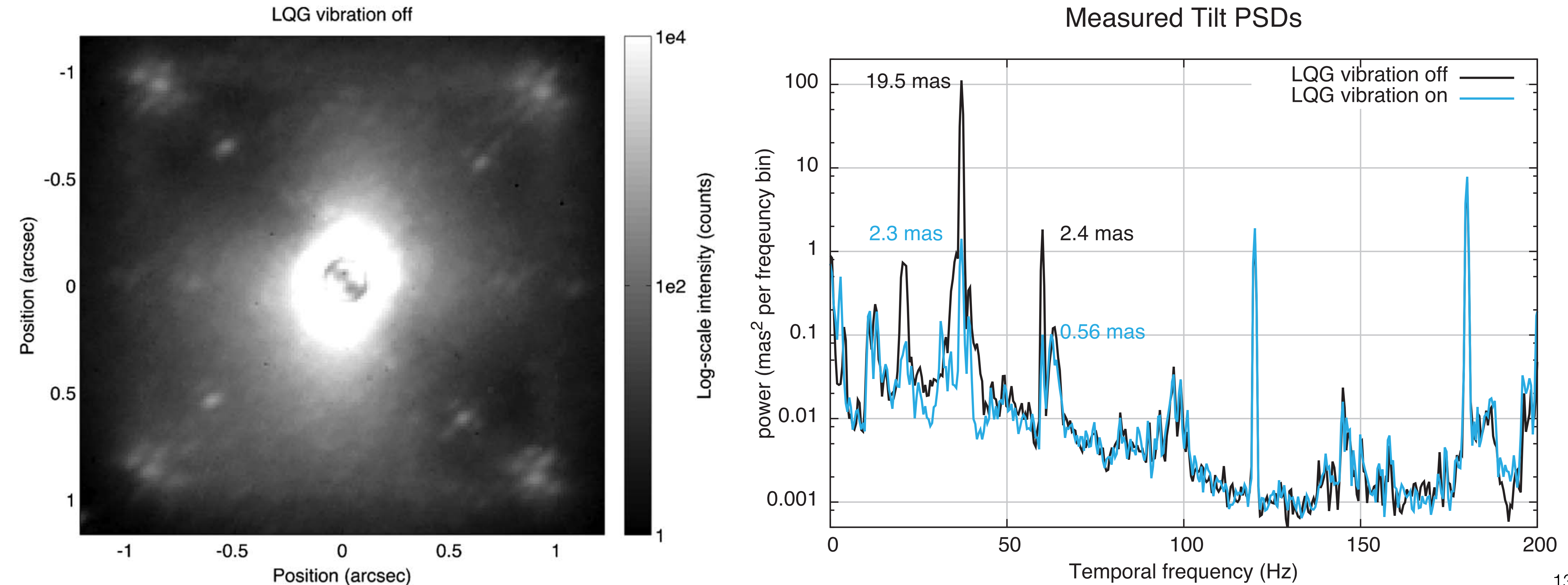


atmosphere errors
“bandwidth WFE”

photon/read noise
“noise WFE”

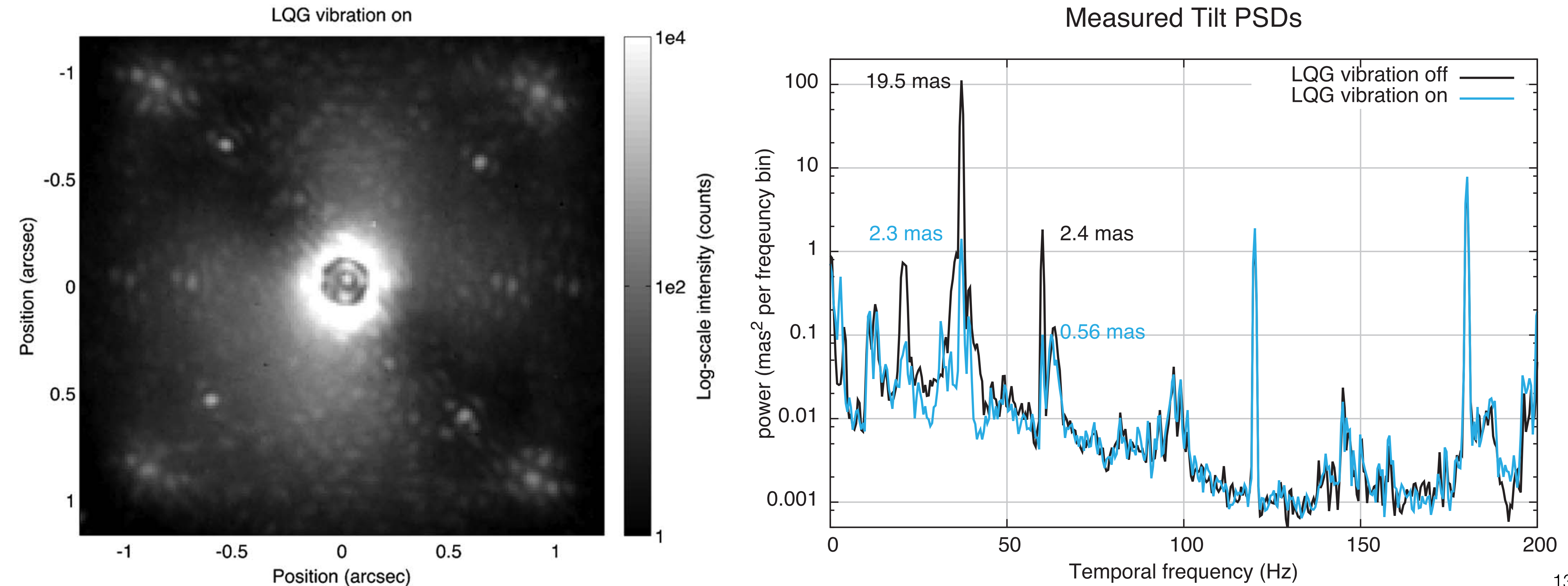
Vibration analysis example: faulty fan

Poyneer+, Appl Opt, 2016

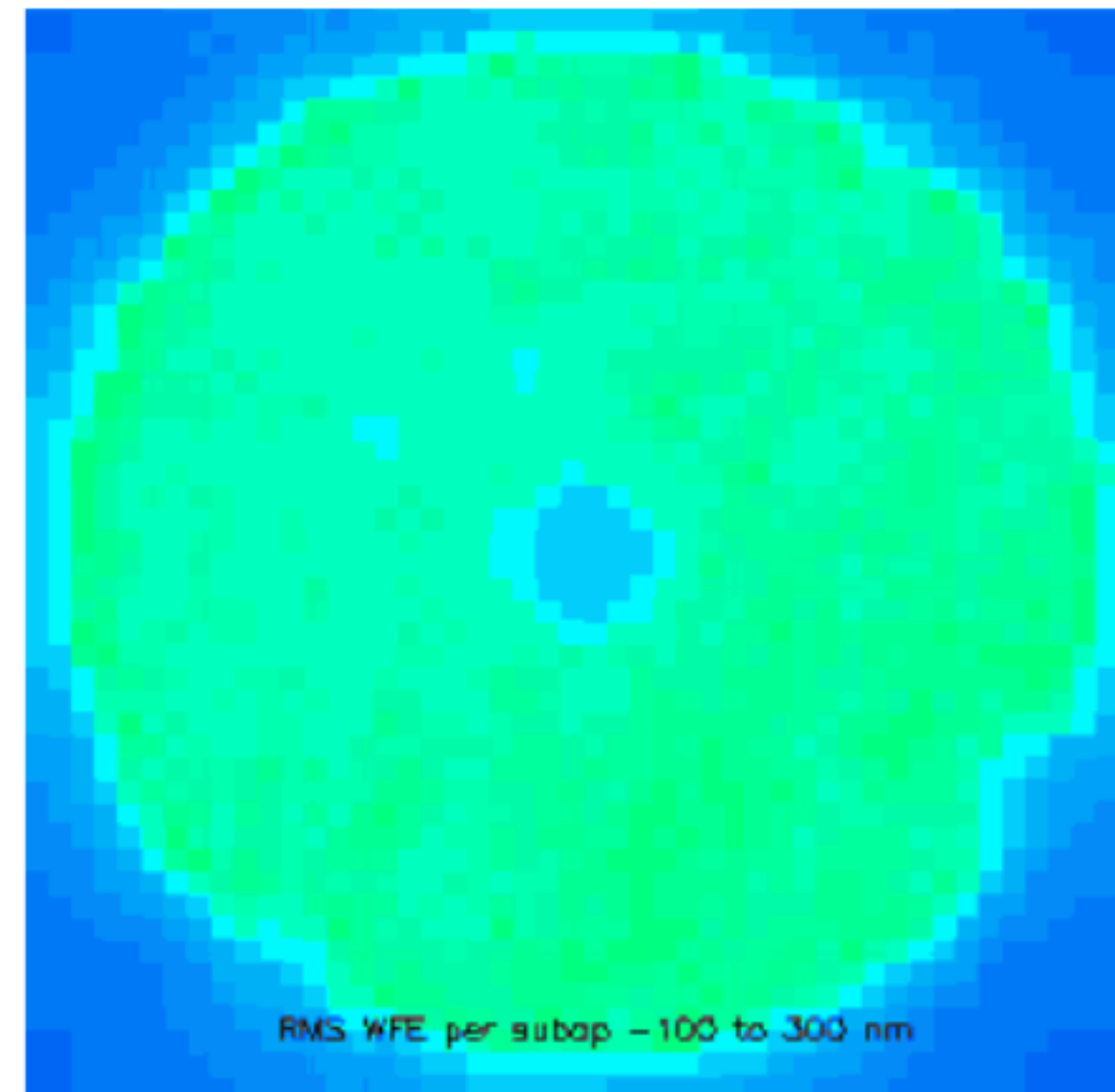
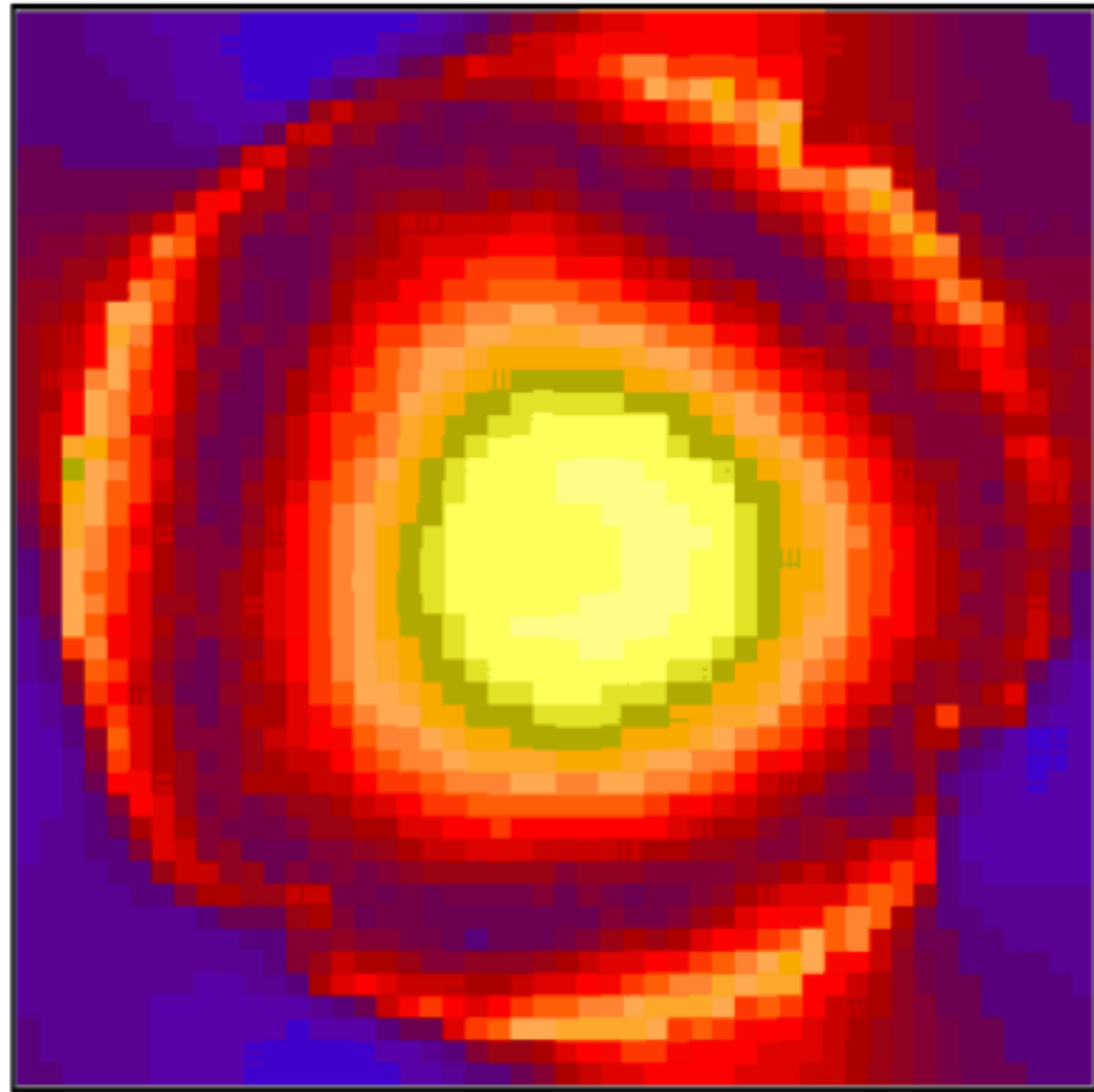


Vibration analysis example: faulty fan

Poyneer+, Appl Opt, 2016

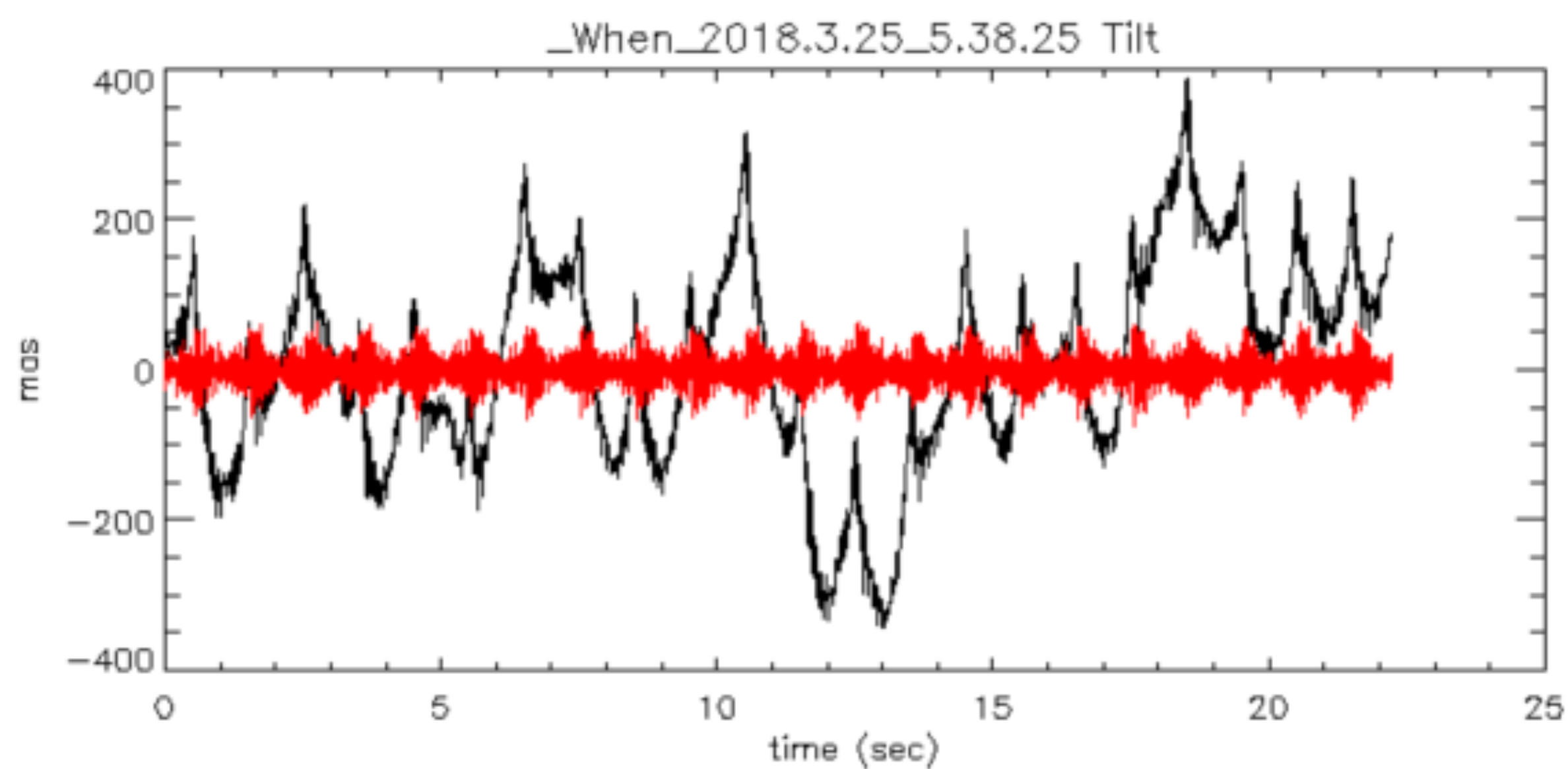
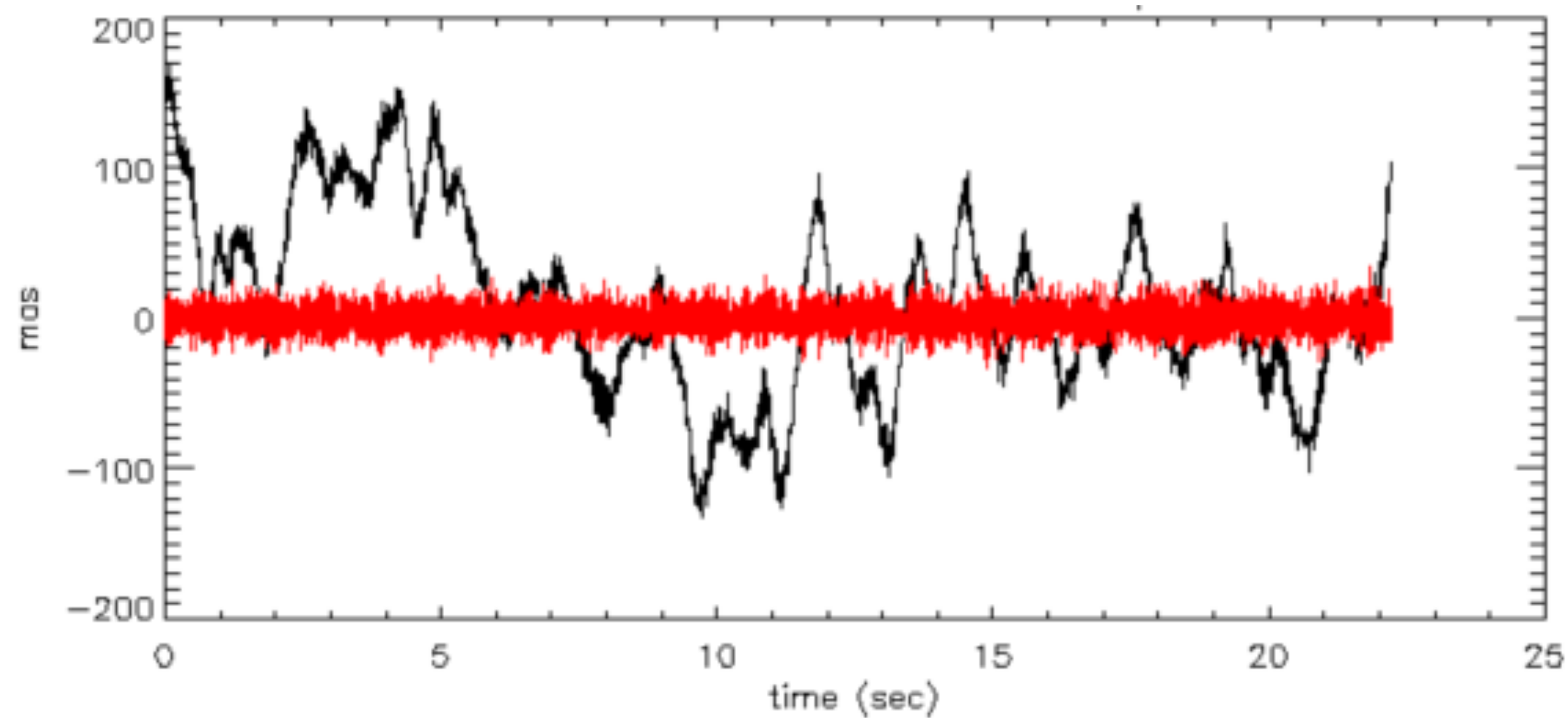


Example: cryocooler controller replace to mitigate M1 60Hz coupling

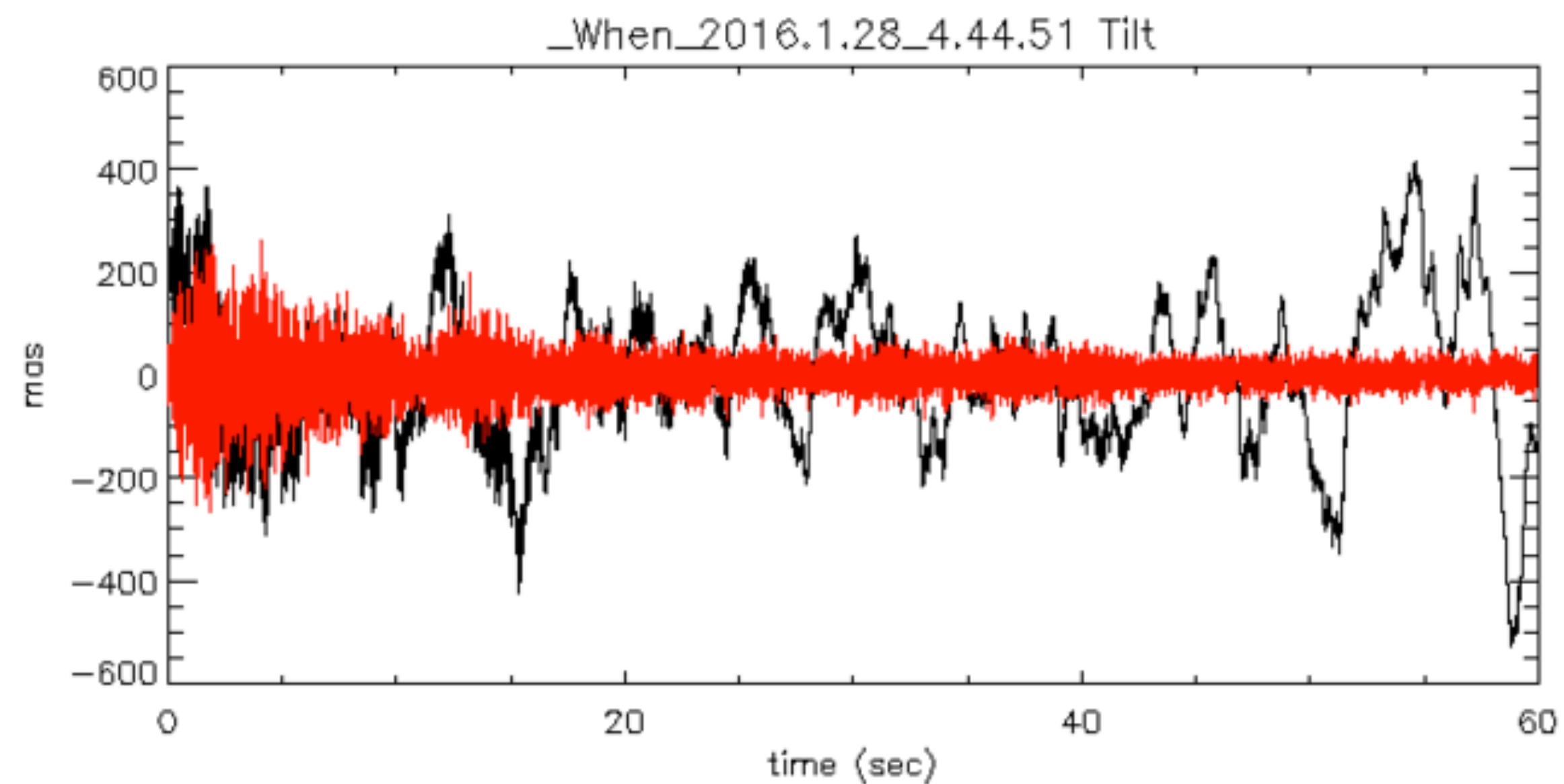
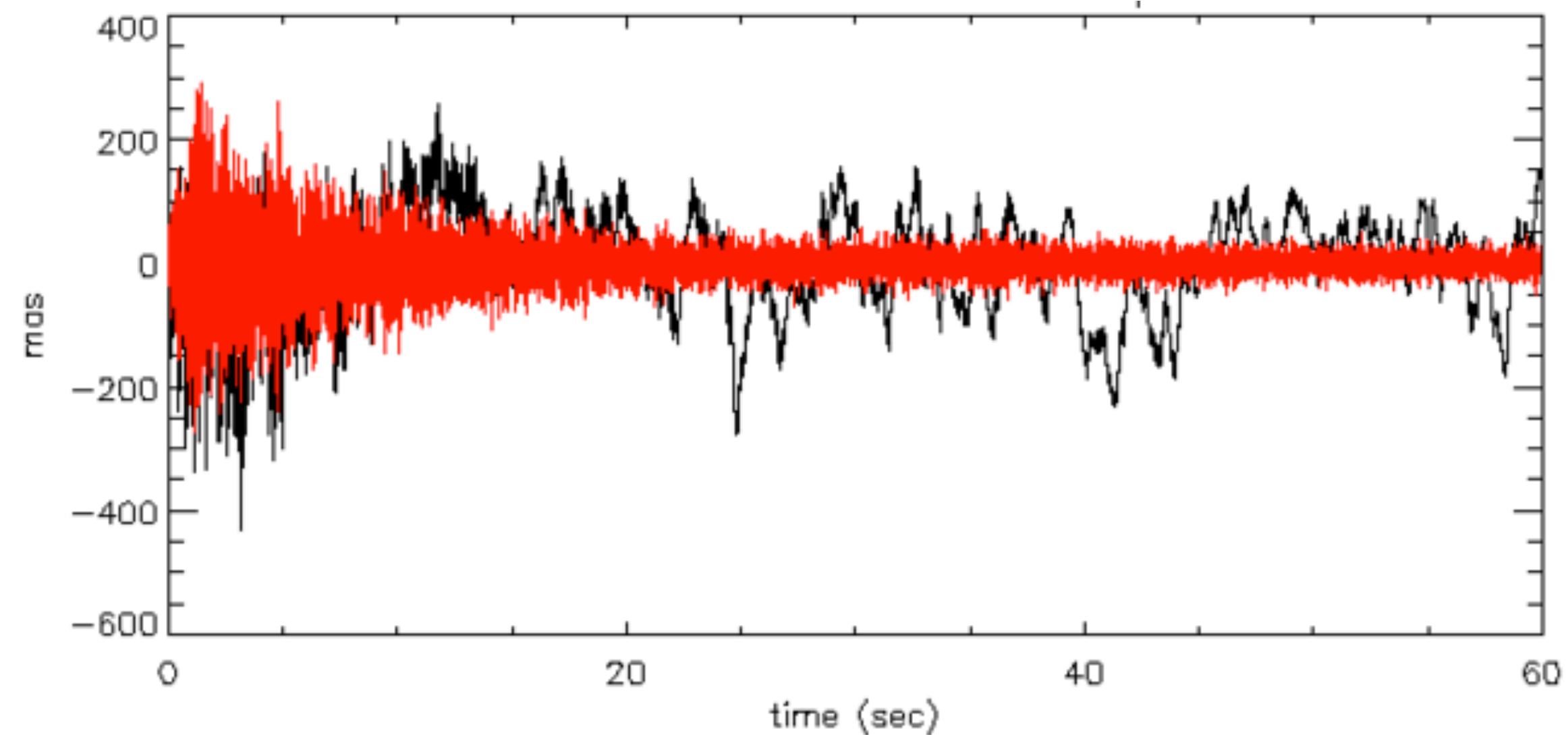


Hartung+, SPIE, 2014

Telescope tracking

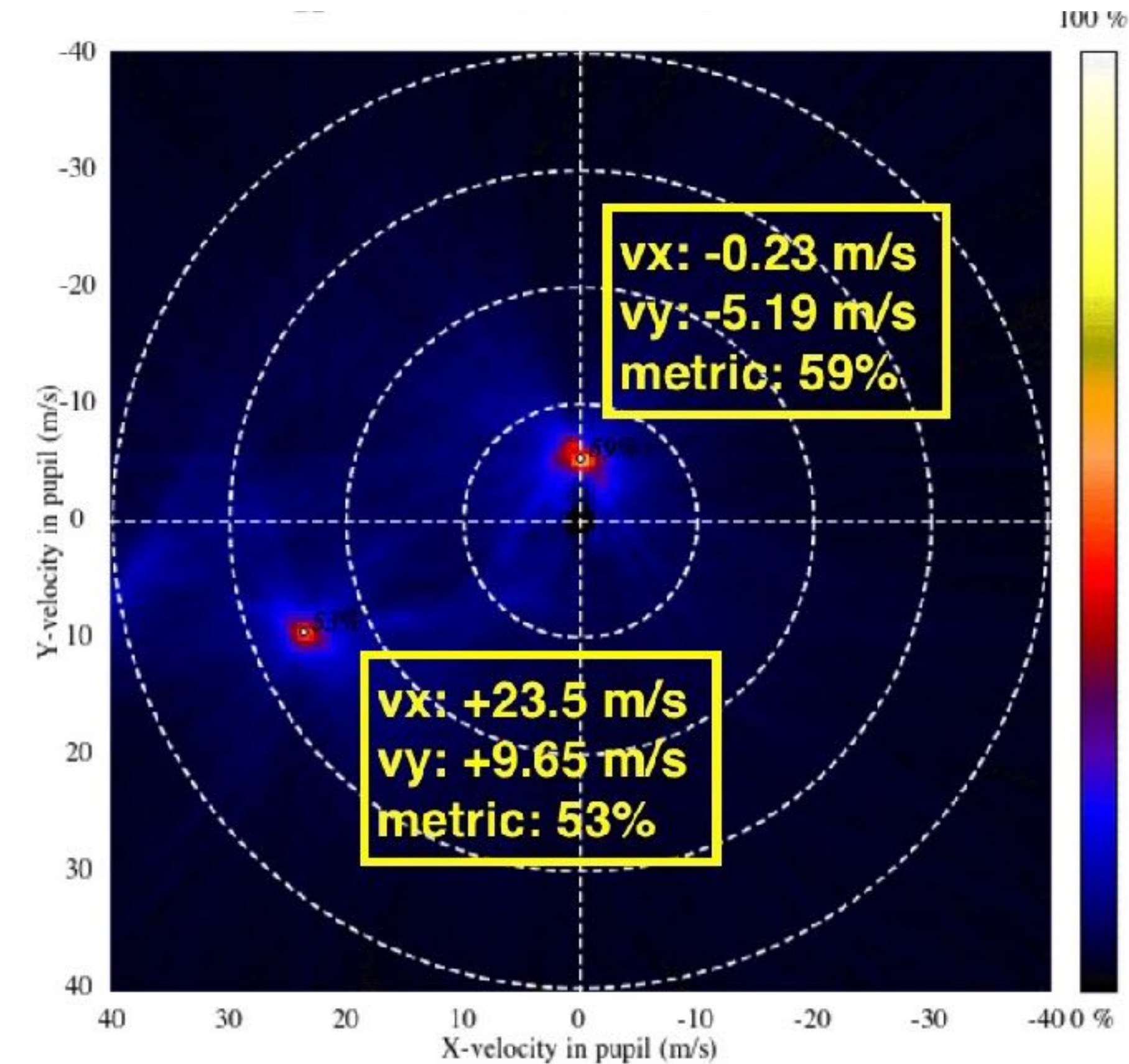


Earthquake



Tangent: site characterization

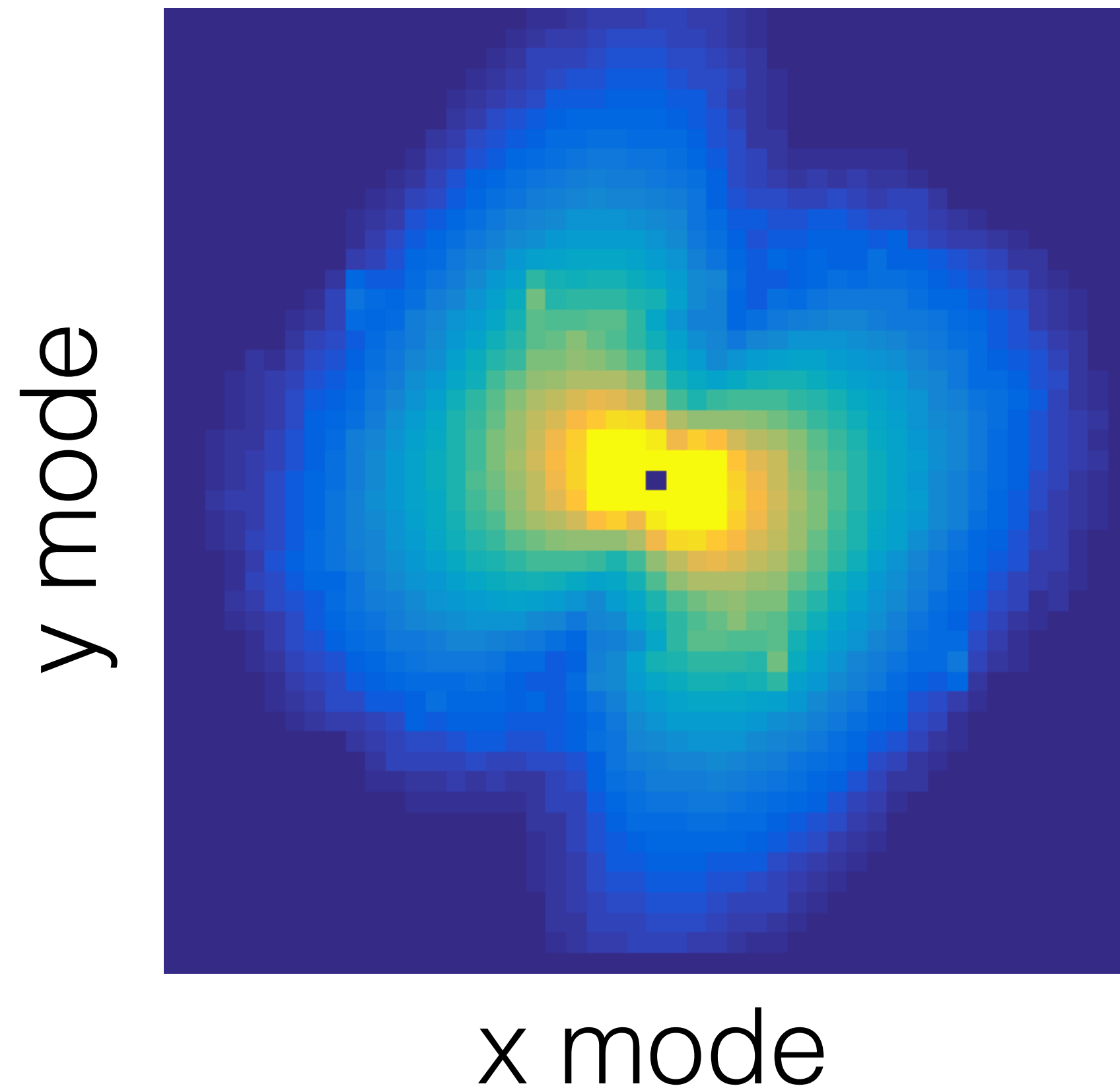
- Regular AO telemetry = regular site monitoring (postprocessing required!!)
- Compare to observatory MASS, DIMM, etc.
- planning upgrades &/or new instruments (AO and seeing-limited)
- What datasets exist for other AO instruments and/or sites?



Sri Srinath - SPIE 2016
Adam Snyder - SPIE 2016

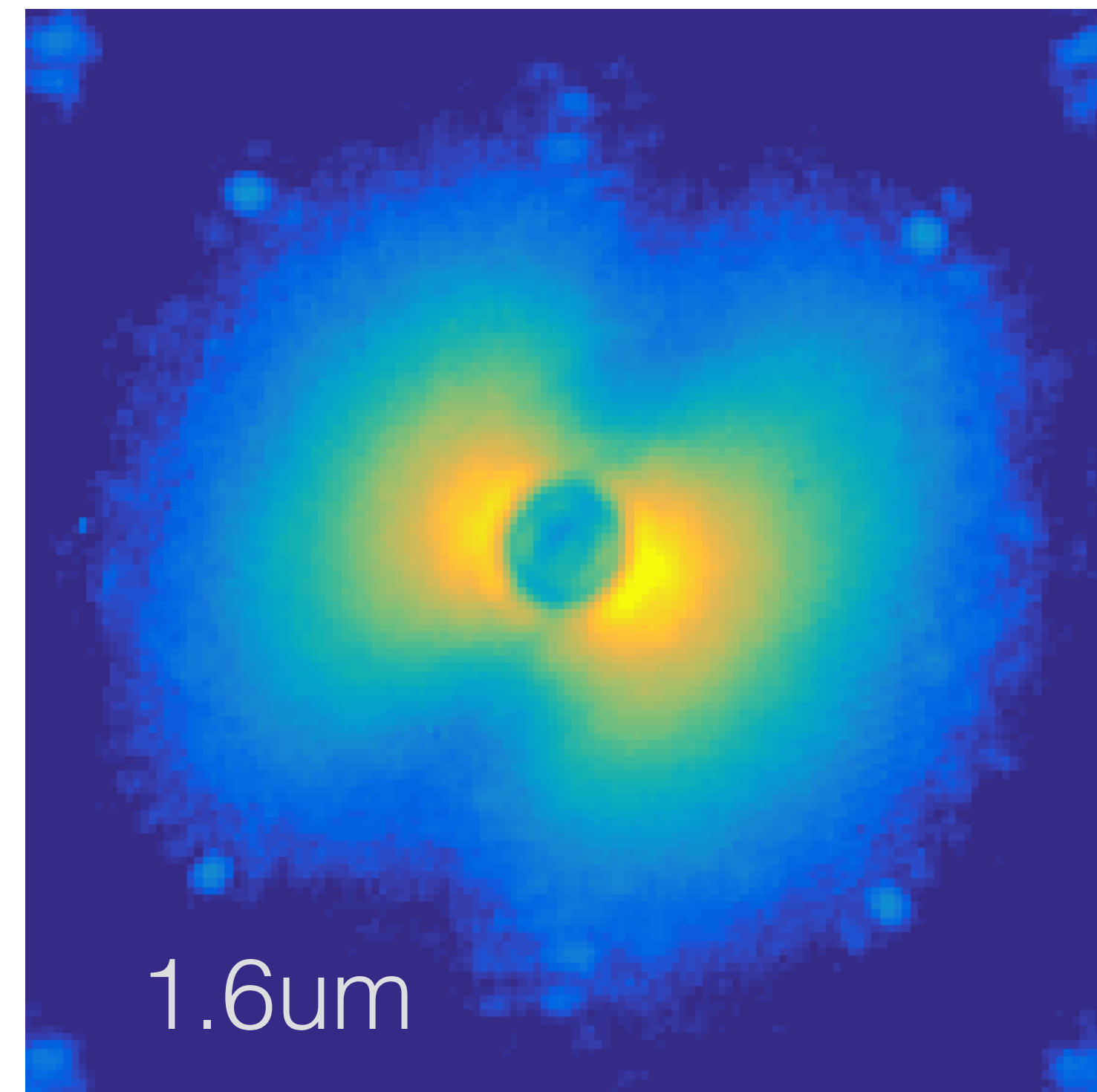
Reconstructed WFE ~ GPI IFS frames

**pseudo-closed loop
WFE² [nm²]**



2016.2.29_22.52.44

IFS img



S20160301S0059_spdc

telemetry for WFIRST CGI

Eric Cady

- LOWFS : full rate images saved
 - realtime x/y centering location of star in every science frame
 - contribution from Z2-Z11 = input to PCA?
- HOWFS uses science camera images themselves

$$\begin{array}{ccccccc} \text{measured} & & \text{incoherent} & & \text{coherent} & & \text{coherent} \\ \text{intensity} & & \text{intensity} & & \text{real } E & & \text{imaginary } E \\ \hline \text{[Image]} & = & \text{[Image]} & + & \text{[Image]} & + i & \text{[Image]}^2 \end{array}$$

The diagram illustrates the mathematical decomposition of measured intensity. It shows a sequence of four circular images. The first image, labeled 'measured intensity', is a grayscale image of a star with a bright central core and a surrounding diffraction pattern. This is followed by an equals sign. The second image, labeled 'incoherent intensity', is a similar grayscale image but with a more uniform, ring-like appearance. This is followed by a plus sign. The third and fourth images are grouped by a large vertical bracket on the right. The third image is labeled 'coherent real E' and shows a complex, colorful (red, yellow, blue) interference pattern. The fourth image is labeled 'coherent imaginary E' and shows a similar but phase-shifted interference pattern. Between the third and fourth images is a plus sign and the imaginary unit 'i'. A superscript '2' is placed at the end of the bracketed group, indicating that the coherent components are squared and summed to form the total coherent intensity.

What AO telemetry do we actually save now?

- most AO data isn't saved!
 - data rate of 100MB to >1 GB / minute for high-order systems
 - manually triggered sets. Few sec to a few min, a few times per target. Sparse sampling!
- lots of AO data is unprocessed!
 - pipelines, databases required but not often allocated resources
 - Design systems for simplified analysis? (eg: Fourier basis sets?)

What is the minimal AO data we need to save?

- Analyze system performance?
- Complement focal plane WFS?
- Complement data reduction?
- What cadence?
- Save everything? Realtime process?
- S/N & error tolerance?
- ?

ground vs. space?

How to use current systems?

- Reach specs on *current* systems
 - Develop AO telem pipelines & infrastructure
 - Identify factors limiting *astrophysics*, not WFE
- What can we test with existing systems?
- ??